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The Administrative Record Staff

FINAL

PHASE III RFI/RI WORK PLAN

ROCKY FLATS PLANT
881 HILLSIDE AREA
(OPERABLE UNIT NO)

U S DEPARTMENT O ENERGY

Rocky Flats Plant
Golden Colorado

ENVIRONMENTAL RESTORATION PROGRAM

October 199

Volume I -- Tex

Department of Energy

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Gentlemen

As required by the Inter-Agency Agreement, we are enclosing two copies of the Phase III RFI/RI Work Plan for the Rocky Flats Plant, 881 Hillside (OUI) This document includes work plans for remedial investigation, feasibility study, environmental evaluation, a human health risk assessment, and a separate quality assurance addendum that pertains to the 881 Hillside work In addition, there are responses to EPA and CDH comments on the final draft of the Work Plan

If you have any questions regarding these documents, please feel free to contact me or Tom Olsen of my staff at 966-2762

Sincerely,

Robert M Nelson, Jr.

Robert M Nelson, Jr.
Manager

Enclosure

FINAL PHASE III RCRA FACILITY INVESTIGATION/REMEDIAL INVESTIGATION

WORK PLAN

ROCKY FLATS PLANT
881 HILLSIDE AREA
(OPERABLE UNIT NO. 1)

ENVIRONMENTAL RESTORATION PROGRAM

U S Department of Energy
Rocky Flats Office
Golden, Colorado

OCTOBER 1990

EXECUTIVE SUMMARY

This document presents the work plan for the Phase III RCRA Facility Investigation/CERCLA Remedial Investigation (RFI/RI) of the 881 Hillside Area (Operable Unit No 1) at the Rocky Flats Plant After an introduction to the site in Section 1 0, the work plan summarizes results of the Phase I and Phase II RIs (Rockwell International, 1987a and 1988a) in Section 2 Section 3 defines Phase III RFI/RI data quality objectives and data needs based on the conclusions from Phases I and II, and Section 4 specifies RFI/RI tasks including a baseline risk assessment and feasibility study Section 5 is the Field Sampling Plan for soils and water which is designed to meet the RFI/RI objectives Section 6 presents plans for an environmental evaluation in the 881 Hillside Area

Sites at the 881 Hillside Area were selected as High Priority Sites as a result of Plant-wide characterization activities which showed elevated concentrations of volatile organic compounds in ground water upgradient from Woman Creek (U S DOE, 1987a) The Phase I and Phase II RIs indicated that the unconfined ground-water flow system is contaminated The most pronounced organic contamination is in the eastern portion of the 881 Hillside Area, with tetrachloroethene, trichloroethene, 1,1-dichloroethene, 1,1-dichloroethane, 1,1,1-trichloroethane, 1,1,2-trichloroethane, and carbon tetrachloride reaching several thousand micrograms per liter in many samples Organic contamination in the western portion of the 881 Hillside area occurs at much lower concentrations Concentrations of metals and inorganics above estimated background levels are considered to represent possible contamination for the purposes of planning the Phase III RFI/RI The eastern portion of the study area showed the highest concentrations of inorganic constituents, with total dissolved solids of approximately 2000 milligrams per liter, and numerous occurrences of nickel, strontium, selenium, zinc, copper, and uranium above background in most wells Other metals exceeded background less frequently and by a smaller margin in this area and elsewhere at Operable Unit No 1

Phase I and Phase II soils investigations indicated tetrachloroethene, trichloroethene, and 1,1,1-trichloroethane contamination in some soil samples Prevalent occurrences of methylene chloride, acetone, and phthalates in soil samples have raised questions of laboratory contamination which prevent definitive conclusions about the actual presence of these contaminants in soils Plutonium and americium were detected above background in soil samples that include the ground surface Windblown radionuclide-bearing dust from

the 903 Pad Area is the suspected source of these radionuclides. Plans for additional characterization of waste sources and soils are described herein.

Tetrachloroethene and trichloroethene are the principal volatile organic compounds which have been detected in surface water samples from a few stations, although the concentrations and frequency of occurrence are low Low concentrations of methylene chloride, acetone, and toluene in the surface water occur at many sampling stations The furthest downgradient surface water samples do not show organic contamination Numerous metals and other inorganic compounds were occasionally above background Gross alpha, gross beta, uranium, and plutonium exceeded background in many of the samples

Proposed sampling and analysis for the RFI/RI, presented in Section 5, will support source characterization and better definition of the nature and extent of soil, ground-water, and surface water contamination Approximately fifty boreholes will be drilled and nineteen monitor wells will be installed for the purposes of source characterization An additional sixteen monitoring wells will be installed to determine the nature and extent of contamination, and to support hydraulic testing for better characterization and prediction of contaminant movement

Based on the Phase I and II results, an interim measures/interim remedial action (IM/IRA) is being implemented at OU 1 The IM/IRA focuses on the collection of contaminated alluvial ground water, and treatment of the ground water to remove organic and inorganic contaminants

Surface soil scrapes, and soil samples for vertical profile analysis will be collected to better characterize the distribution of radionuclides, and to complement an investigation of surface soils over an 800 acre area which is planned for Operable Unit No 2, east of the 881 Hillside Area Three new sediment sampling stations will be established to enable characterization of sediments that are more directly associated with the 881 Hillside than sediment samples analyzed in previous investigations

A baseline risk assessment plan is provided in Sections 4 1 6 and 6 The baseline risk assessment includes both a public health evaluation and environmental evaluation Section 4 1 6 focuses on the public health evaluation including contaminant identification, exposure assessment, toxicity assessment, and risk characterization This section also briefly discusses the environmental evaluation, however, the details are provided in Section 6, the Environmental Evaluation Plan This plan was prepared to provide a framework for addressing environmental effects as a result of exposure to contaminants from the 881 Hillside Area. The plan presents a three-stage approach for conducting the environmental evaluation The sequential approach was designed to ensure that all procedures to be performed are appropriate, necessary, and sufficient to adequately characterize the nature and extent of the environmental impacts resulting from contaminants at 881 Hillside

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GLOSSARY OF ACRONYMS

ACRONYM	MEANING
AEC	Atomic Energy Commission
ALAD	Amino-lerulinic acid dehydrase
ARARs	Applicable or Relevant and Appropriate Requirements
AWQC	Ambient Water Quality Criteria
BCFs	Bioconcentration Factors
CAD	Corrective Action Decision
CCl_4	Carbon Tetrachloride
CCR	Colorado Code of Regulations
CDH	Colorado Department of Health
CEARP	Comprehensive Environmental Assessment and Response Program
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
CLP	Contract Laboratory Program
CFR	Code of Federal Regulations
$CHCl_3$	Chloroform
cm/s	Centimeters per second
CMS/FS	Corrective Measures Study/Feasibility Study
CWA	Clean Water Act
DQO	Data Quality Objectives
1,1-DCA	1,1-dichloroethane
1,2-DCA	1,2-dichloroethane
1,1-DCE	1,1-dichloroethene
1,2-DCE	1,2-dichloroethene
dpm/g	Disintegrations per Minute per Gram
DOE	Department of Energy
DRCOG	Denver Regional Council of Governments
EPA	Environmental Protection Agency
ER	Environmental Restoration Program
ERDA	Energy Research and Development Administration
FFACO	Federal Facility Agreement and Consent Order
FR	Federal Register
FS	Feasibility Study
FSP	Field Sampling Plan
ft/ft	Foot Per Foot
ft/yr	Foot Per Year
GFAA	Graphite Furnace Absorption Spectroscopy
GRRASP	General Radiochemistry and Routine Analytical Services Protocol
GPM	Gallons Per Minute

GLOSSARY OF ACRONYMS
(continued)

ACRONYM	MEANING
HEAST	Health Effects Assessment Summary Tables
HSL	Hazardous Substance List
HSP	Health and Safety Plan
IHSS	Individual Hazardous Substance Site
IAG	Inter-Agency Agreement - the Federal Facility Agreement & Consent Order (FFACO)
ICP	Inductively Coupled Argon Plasma Emission Spectroscopy
IM/IRA	Interim Measures/Interim Remedial Action
IRIS	Integrated Risk Information System
Kg	Kilograms
m	Meter
MATC	Maximum Allowable Tissue Concentrations
mCi/m^2	micoCurie per Square Meter
MCL	Maximum Contaminant Level
MCLG	Maximum Contaminant Level Goal
MDA	Minimum Detectable Activity
mg	Milligrams
mg/kg	Milligrams Per Kilogram
mg/l	Milligrams Per Liter
ml	Milliliters
mm	Millimeters
NCP	National Contingency Plan
nm	Nanometers
NPDES	National Pollutant Discharge Elimination System
OSWER	Office of Solid Waste and Emergency Response
PCE	Tetrachloroethene
pCi/g	picoCuries per Gram
pCi/l	picoCuries per Liter
QA/QC	Quality Assurance/Quality Control
QAPjP	Quality Assurance Project Plan
RAAMP	Radioactive Ambient Air Monitoring Program
RAID	Superfund Risk Assessment Information Directory
RAS	Routine Analytical Services
RCRA	Resource Conservation and Recovery Act of 1976
RfD	Reference Dose
RFI/RI	RCRA Facility Investigation/Remedial Investigation
RI	Remedial Investigation
ROD	Record of Decision

GLOSSARY OF ACRONYMS
(continued)

ACRONYM	MEANING
SAP	Sampling and Analysis Plan
SARA	Superfund Amendments and Reauthorization Act of 1986
SDWA	Safe Drinking Water Act
SOP	Standard Operating Procedures
SW	Surface Water Monitoring Station
SWMU	Solid Waste Management UnitTarget Analyte List
TAL	Target Analyte List
TBC	To Be Considered
1,1,1-TCA	1,1,1-trichloroethane
1,1,2-TCA	1,1,2-trichloroethane
TCE	Trichloroethene
TCL	Target Compound List
TDS	Total Dissolved Solids
TOSCO	The Oil Shale Company
TSP	Treatability Studies Plan
μCi	Microcuries
$\mu g/\ell$	Micrograms Per Liter
μg/kg	Micrograms Per Kilogram
μm	Micrometers

SECTION 1

INTRODUCTION

This document presents the work plan for the Phase III RCRA Facility Investigation/CERCLA Remedial Investigation (RFI/RI) of the 881 Hillside Area (Operable Unit No 1) at the Rocky Flats Plant. It addresses characterization of contaminant sources as well as the nature and extent of contamination in soils, ground water, and surface water The work plan also presents the tasks that must be completed in the performance of the RCRA Corrective Measure Study/CERCLA Feasibility Study (CMS/FS)

This investigation is part of a comprehensive, phased program of site characterization, remedial investigations, feasibility studies, and remedial/corrective actions currently in progress at the Rocky Flats Plant These investigations are pursuant to the U S Department of Energy (DOE) Environmental Restoration (ER) Program [formerly known as the Comprehensive Environmental Assessment and Response Program (CEARP)], a Compliance Agreement between DOE, the U S Environmental Protection Agency (EPA) and the State of Colorado Department of Health (CDH) dated July 31, 1986, and the Federal Facility Agreement and Consent Order (FFACO) [known as the Inter-Agency Agreement (IAG)] The program developed by DOE, EPA, and CDH in response to the agreements addresses RCRA and CERCLA issues and has been integrated with the ER Program In accordance with the IAG, the CERCLA terms "Remedial Investigation" and "Feasibility Study" in this document are considered equivalent to the RCRA terms "RCRA Facility Investigation" and "Corrective Measures Study"

1 1 ENVIRONMENTAL RESTORATION PROGRAM

The ER Program is designed to investigate and clean up contaminated sites at DOE facilities The ER Program is being implemented in five phases Phase 1 (Installation Assessment) includes preliminary assessments and site inspections to assess potential environmental concerns Phase 2 (Remedial Investigations) includes planning and implementation of sampling programs to delineate the magnitude and extent of contamination at specific sites and to evaluate potential contaminant migration pathways Phase 3 (Feasibility Studies) evaluates remedial alternatives and develops remedial action plans to mitigate environmental problems identified as needing correction in Phase 2 Phase 4 (Remedial Design/Remedial

Action) includes design and implementation of site-specific remedial actions selected on the basis of Phase 3 feasibility studies. Phase 5 (Compliance and Verification) implements monitoring and performance assessments of remedial actions, and verifies and documents the adequacy of remedial actions carried out under Phase 4 Phase 1 has already been completed at Rocky Flats Plant (U S DOE, 1986), and Phases 2, 3, and 4 are currently in progress for Operable Unit No 1

Phase 2 activities at Operable Unit No 1 include a Phase I and a Phase II RI An initial (Phase I) field program was completed at the 881 Hillside Area in 1987, and a draft Phase I RI report was submitted to EPA and CDH in July 1987 (Rockwell International, 1987a) Based on results of that investigation, a second phase of field work was conducted at the 881 Hillside in the fall of 1987 A draft Phase II RI was submitted to EPA and CDH in March 1988 (Rockwell International, 1988a), and in October 1988 the DOE received written comments on the draft Phase II RI

ER Program Phase 3 activities include submittal of a draft FS report to EPA and CDH in March 1988 (Rockwell International, 1988b) This document was submitted with the draft Phase II RI report, and EPA comments on the FS were received with the Phase II RI comments Written responses to the March 1988 RI/FS were prepared and forwarded to EPA in February 1989 (Rockwell International, 1989a) An interim remedial action plan has also been developed to collect and treat contaminated alluvial ground water at Operable Unit No 1 (U S DOE, 1990a) The plan was released for public comment during October and November 1989 and finalized in January 1990 Construction of the interim remedial action was started in January 1990 A final remedial action will be proposed based on Phase I, II, and III investigations

A draft Phase III RFI/RI Work Plan was submitted to EPA and CDH in February 1990 (EG&G, 1990a) This final Phase III plan incorporates comments received by EPA and CDH in May 1990 Written responses to these comments are being submitted under separate cover

1 2 WORK PLAN OVERVIEW

This Phase III RFI/RI Work Plan for the 881 Hillside Area presents results of the Phase I and Phase II RIs, defines data quality objectives and data needs based on that investigation, specifies RI/FS tasks, and presents a Field Sampling Plan (FS) The plan incorporates agency comments on the March 1988 RI/FS This section (1 Introduction) presents site locations and descriptions, and Section 2 presents results of the previous RIs. Included in Section 2 are Phase I and Phase II characterization results for site geology and hydrology as well as the nature and extent of contamination in soils, ground water, surface water, and sediments Section 3 discusses data quality objectives for the Phase III investigation Section 4 specifies RI/FS tasks to be performed, and Section 5 presents the FSP to meet RI/FS objectives Section 6 presents a detailed environmental evaluation plan for the 881 Hillside Area.

1 3 BACKGROUND AND PHYSICAL SETTING

1 3 1 Background

The Rocky Flats Plant is a government-owned, contractor-operated facility, which is part of the nationwide nuclear weapons production complex The Plant was operated for the U S Atomic Energy Commission (AEC) from its inception in 1951 until the AEC was dissolved in January 1975 At that time, responsibility for the Plant was assigned to the Energy Research and Development Administration (ERDA), which was succeeded by the DOE in 1977 Dow Chemical U S A., an operating unit of the Dow Chemical Company, was the prime operating contractor of the facility from 1951 until June 30, 1975 Rockwell International was the prime contractor responsible for operating the Rocky Flats Plant from July 1, 1975, until December 31, 1989 EG&G Rocky Flats, Inc, became the prime contractor at the Rocky Flats Plant on January 1, 1990, and currently operates the Plant

1 3 1 1 Plant Operations

The primary mission of the Rocky Flats Plant is to fabricate nuclear weapon components from plutonium, uranium, and other non-radioactive metals (principally beryllium and stainless steel) Parts made at the Plant are shipped elsewhere for assembly In addition, the Plant reprocesses components after they are removed from obsolete weapons for recovery of plutonium

Both radioactive and nonradioactive wastes are generated in the production process. Current waste handling practices involve on-site and off-site recycling of hazardous materials, on-site storage of hazardous and radioactive mixed wastes, and off-site disposal of solid radioactive materials at another DOE facility However, both storage and disposal of hazardous and radioactive wastes occurred on site in the past. Preliminary assessments under the ER Program identified some of the past on-site storage and disposal locations as potential sources of environmental contamination

1 3 1 2 Previous Investigations

Various studies have been conducted at the Rocky Flats Plant to characterize environmental media and to assess the extent of radiological and chemical contaminant releases to the environment The investigations performed prior to 1986 are summarized in Rockwell International (1986a) and include

1) Detailed descriptions of the regional geology (Malde, 1955, Spencer, 1961, Scott, 1960, 1963, 1970, 1972 and 1975, Van Horn, 1972 and 1976, U S DOE, 1980, Dames and Moore, 1981, and Robson et al , 1981a and 1981b)

2) Several drilling programs beginning in 1960 that resulted in the construction of approximately 60 monitor wells by 1982

3) An investigation of surface and ground-water flow systems by the U S Geological Survey (Hurr, 1976)

4) Environmental, ecological, and public health studies which culminated in an environmental impact statement (U S DOE, 1980)

5) A summary report on ground-water hydrology using data from 1960 to 1985 (Hydro-Search, Inc., 1985)

6) A preliminary electromagnetic survey of the Plant perimeter (Hydro-Search, Inc , 1986)

7) A soil gas survey of the Plant perimeter and buffer zone (Tracer Research, Inc , 1986)

8) Routine environmental monitoring programs addressing air, surface water, ground water, and soils (Rockwell International, 1975 through 1985, 1986b, and 1987b)

In 1986, two major investigations were completed at the Plant The first was the ER Program Phase 1 installation assessment (U S DOE, 1986) which included analyses and identification of current operational activities, active and inactive waste sites, current and past waste management practices, and potential environmental pathways through which contaminants could be transported A number of sites were identified that could potentially have adverse impacts on the environment. These sites were designated as Solid Waste Management Units (SWMUs) by Rockwell International (1987c) and were divided into three categories

1) Hazardous waste management units that will continue to operate and need a RCRA operating permit.

2) Hazardous waste management units that will be closed under RCRA interim status

3) Inactive waste management units that will be investigated and cleaned up under Section 3004(u) of RCRA or CERCLA.

The IAG redefines the SWMUs within the second and third categories as Individual Hazardous Substance Sites (IHSSs) This term is used hereinafter, however, no RCRA or CERCLA regulatory distinction in the use of the terms "site", "unit", or "SWMU" is intended in this document

The second major investigation completed at the Plant in 1986 involved a hydrogeologic and hydrochemical characterization of the entire Plant site Plans for this study were presented in Rockwell International (1986c and 1986d), and study results were reported in Rockwell International (1986e) Investigation results indicated four areas to be significant contributors to environmental contamination, with each area containing several sites The areas are the 881 Hillside Area, the 903 Pad Area, the Mound Area, and the East Trenches Area

Sites at the 881 Hillside Area were selected as High Priority Sites because of the elevated concentrations of volatile organic compounds detected in the ground water, the relatively permeable soils, and the proximity of the area to a surface water drainage RFI/RI activities to date at the 881 Hillside Area are discussed in more detail in Section 2

1 3 2 Physical Setting

The Rocky Flats Plant is located in northern Jefferson County, Colorado, approximately 16 miles northwest of Denver (Figure 1-1) The Plant consists of approximately 6,550 acres of federally owned land

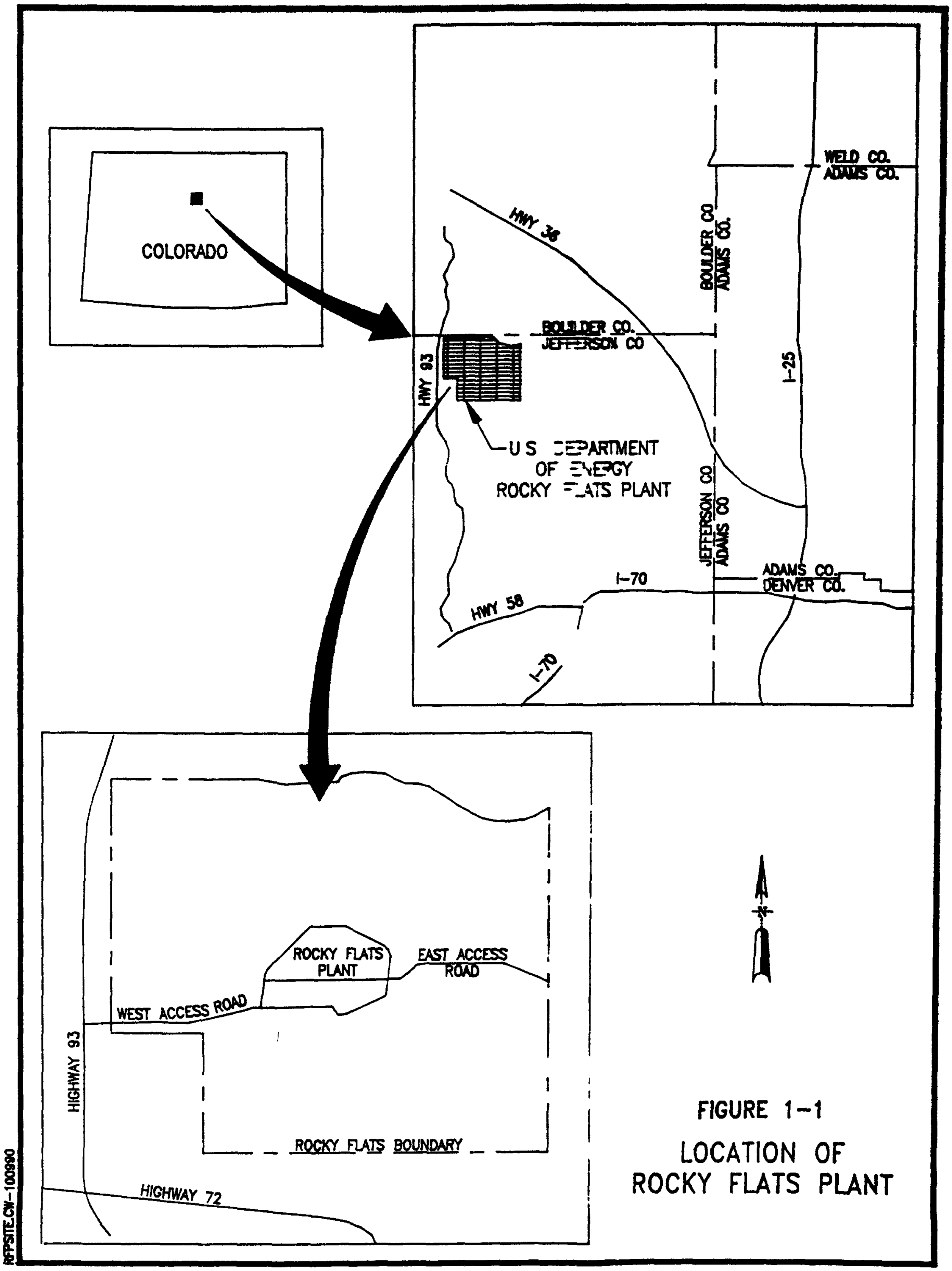

FIGURE 1-1
LOCATION OF
ROCKY FLATS PLANT

in Sections 1 through 4 and 9 through 15 of T2S, R70W, 6th Principal Meridian. Major buildings are located within the Plant security area of approximately 400 acres. The security area is surrounded by a buffer zone of approximately 6,150 acres (Figure 1-2)

1 3 2 1 Topography

The natural environment of the Plant and vicinity is influenced primarily by its proximity to the Front Range of the Rocky Mountains. The Plant is directly east of the north-south trending Rocky Mountains, with an elevation of approximately 6,000 feet above sea level Rocky Flats Plant is located on a broad, eastward sloping plain of coalescing alluvial fans developed along the Front Range The fans extend about five miles in an eastward direction from their origin at Coal Creek Canyon and terminate on the east at a break in slope to low rolling hills The continental divide is about 16 miles west of the Plant The operational area at the Plant is located near the eastern edge of the fans on a terrace between stream-cut valleys (North Walnut Creek and Woman Creek)

1 3 2 2 Surface Water Hydrology

Three intermittent streams drain the Rocky Flats Plant with flow generally from west to east These drainages are Rock Creek, Walnut Creek, and Woman Creek (Figure 1-2) Rock Creek drains the northwestern corner of the Plant and flows northeast through the buffer zone to its off-site confluence with Coal Creek An east-west trending topographic divide bisects the Plant separating the Walnut and Woman Creek drainages North and South Walnut Creeks and an unnamed tributary drain the northern portion of the Plant security area These three forks of Walnut Creek join in the buffer zone and flow to Great Western Reservoir approximately one mile east of the confluence Woman Creek drains the southern Rocky Flats Plant buffer zone flowing eastward to Standley Reservoir The South Interceptor Ditch lies between the Plant and Woman Creek The South Interceptor Ditch collects runoff from the southern Plant security area and diverts it to Pond C-2, where it is monitored in accordance with the Plant National Pollutant Discharge Elimination System (NPDES) permit prior to discharge to Woman Creek

1.3.2.3 Regional and Local Hydrogeology

Geologic units at the Rocky Flats Plant (in descending order) are the surficial units (Rocky Flats Alluvium, various terrace alluviums, valley fill alluvium, and colluvium) (Figure 1-3) and bedrock (Arapahoe Formation, Laramie Formation, and Fox Hills Sandstone) (Figure 1-4) Ground water occurs under unconfined conditions in both the surficial and subcropping bedrock units. In addition, confined ground-water flow occurs in bedrock sandstones.

Rocky Flats Alluvium

The Rocky Flats Alluvium underlies a large portion of the Plant The alluvium is a broad fan deposit consisting of a topsoil layer underlain by up to 100 feet of silt, clay, sand, and gravel Unconfined ground-water flow occurs in the Rocky Flats Alluvium which is relatively permeable Recharge to the alluvium is from precipitation, snowmelt, and water losses from ditches, streams, and ponds that are cut into the alluvium. General water movement in the Rocky Flats Alluvium is from west to east and toward the drainages. Ground-water flow is also controlled by paleochannels in the top of bedrock The water table in the Rocky Flats Alluvium rises in response to recharge during the spring and declines during the remainder of the year Discharge from the alluvium occurs at minor seeps in the colluvium that covers the contact between the alluvium and bedrock along the edges of the valleys. The Rocky Flats Alluvium thins east of the Plant boundary and does not directly supply water to wells located downgradient of Rocky Flats Plant.

Other Alluvial Deposits

Various other alluvial deposits occur topographically below the Rocky Flats Alluvium in the Plant drainages Colluvium (slope wash) mantles the valley side slopes between the Rocky Flats Alluvium and the valley bottoms In addition, remnants of younger terrace deposits including the Verdos, Slocum, and Louviers Alluvia occur occasionally along the valley side slopes Recent valley fill alluvium occurs in the active stream channels

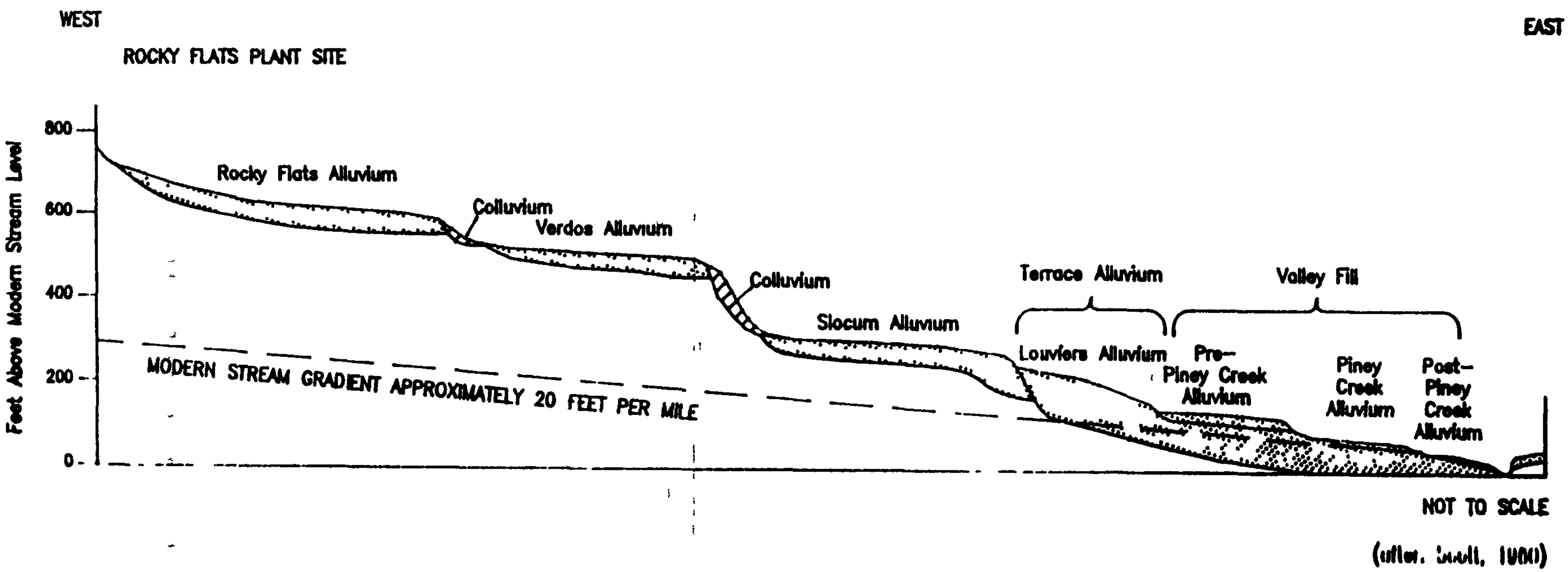

FIGURE 1-3

EROSIONAL SURFACES AND ALLUVIAL DEPOSITS
EAST OF THE FRONT RANGE, COLORADO

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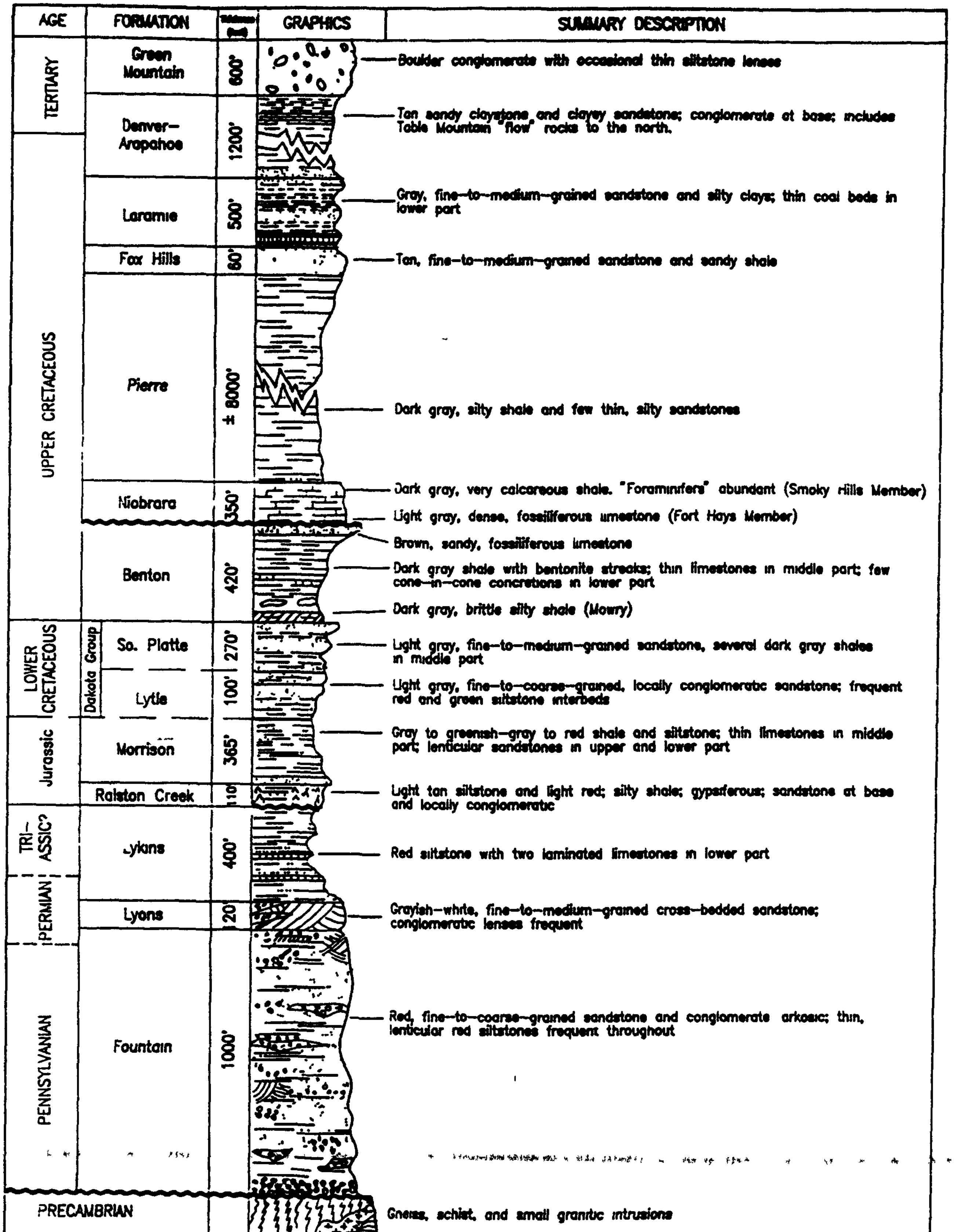

(after LeRoy and Weimer, 1971)

FIGURE 1–4

GENERALIZED STRATIGRAPHIC SECTION, GOLDEN–MORRISON AREA

STRATSEC.pj–121189

Unconfined ground-water flow occurs in these surficial units. Recharge is from precipitation, percolation from streams during periods of surface water runoff, and by seeps discharging from the Rocky Flats Alluvium. Discharge is by evapotranspiration and by seepage into other geologic formations and streams. The direction of ground-water flow is generally downslope through colluvial materials and then along the course of the stream in valley fill materials. During periods of high surface water flow, water is lost to bank storage in the valley fill alluvium and returns to the stream after the runoff subsides.

Arapahoe Formation

The Arapahoe Formation underlies surficial materials beneath most of the Plant except beneath the western portion of the Plant. From approximately the middle of the west buffer zone and west almost to Highway 93, the Laramie Formation unconformably underlies the Rocky Flats Alluvium The Arapahoe formation is a fluvial deposit composed of overbank and channel deposits It consists predominantly of claystones with some siltstones and sandstones. Total formation thickness varies up to 270 feet (Robson et al , 1981a), and the unit is nearly flat-lying beneath the central and eastern portions of the Plant The sandstone bodies within the claystone are composed of very fine-grained sand, silt, and clay A site-wide geologic characterization is ongoing at the Plant to further characterize bedrock geology (EG&G, 1990b and Rockwell International, 1989b)

The Arapahoe Formation is recharged by ground-water movement from overlying surficial deposits. The main recharge areas are under the Rocky Flats Alluvium, although some recharge from the colluvium and valley fill alluvium likely occurs along the stream valleys Recharge is greatest during the spring and early summer when rainfall and stream flow are at a maximum and water levels in the Rocky Flats Alluvium are high Ground-water movement in the Arapahoe Formation is generally toward the east, although flow within individual sandstones is controlled locally by the channel geometries Regionally, ground-water flow in the Arapahoe Formation is toward the South Platte River in the center of the Denver Basin (Robson et al, 1981a)

Laramie Formation and Fox Hills Sandstone

The Laramie Formation underlies the Arapahoe Formation and is composed of two units a thick upper unit composed predominantly of claystone and a lower unit which contains coal and sandstone The upper Laramie Formation is greater than 700 feet thick and is of very low hydraulic conductivity; therefore, the U S Geologic Survey (Hurr, 1976) concludes that Plant operations will not impact any units below the upper claystone unit of the Laramie Formation.

The lower sandstone unit of the Laramie Formation and the underlying Fox Hills Sandstone comprise a regionally important aquifer in the Denver Basin known as the Laramie-Fox Hills Aquifer (Robson, 1983) These units subcrop west of the Plant and can be seen in clay pits excavated through the Rocky Flats Alluvium The steeply dipping beds of these units quickly flatten to the east. Recharge to the aquifer occurs along the rather limited outcrop area exposed to surface water flow and leakage along the Front Range (Robson et al, 1981b)

1 3 2 4 Meteorology

The area surrounding the Rocky Flats Plant has a semiarid climate characteristic of much of the central Rocky Mountain region Approximately forty percent of the 15-inch annual precipitation falls during the spring season, much of it as wet snow Thunderstorms (June to August) account for an additional thirty percent of the annual precipitation. Autumn and winter are drier seasons, accounting for nineteen and eleven percent of the annual precipitation, respectively Snowfall averages 85 inches per year, falling from October through May (U S DOE, 1980)

Special attention has been focused on dispersion meteorology surrounding the Plant due to the remote possibility that significant atmospheric releases might affect the Denver metropolitan area Studies of air flow and dispersion characteristics (e g, Hodgin, 1983 and 1984) indicate that drainage flows (winds coming down off the mountains to the west) turn and move toward the north and northeast along the South Platte River valley and pass to the west and north of Brighton, Colorado (U S DOE, 1986)

1 3 2.5 Surrounding Land Use and Population Density

The Rocky Flats Plant is located in a rural area. Approximately 50 percent of the area within ten miles of the Rocky Flats Plant is in Jefferson County The remainder is located in Boulder County (40 percent) and Adams County (10 percent) According to the 1973 Colorado Land Use Map, 75 percent of this land was unused or was used for agriculture Since that time, portions of this land have been converted to housing, with several new housing subdivisions being started within a few miles of the buffer zone

A recent demographic study shows that approximately 12 2 million people lived within 50 miles of the Rocky Flats Plant in 1989 (U S DOE, 1990b) Approximately 9,100 people lived within five miles of the Plant in 1989 (U S DOE 1990b) The most populous sector was to the southeast, toward the center of Denver Recent population estimates registered by the Denver Regional Council of Governments (DRCOG) for the eight-county Denver metro region have shown distinct patterns of growth between the first and second halves of the decade Between 1980 and 1985, the population of the eight-county region increased by 197,890, a 2 4 percent annual growth rate Between 1985 and 1989 a population gain of 71,575 was recorded, representing a 1 0 percent annual increase (the national average) The 1989 population showed an increase of 2,225 (or 0 1 percent) from the same date in 1988 (DRCOG, 1989)

There are eight public schools within six miles of the Rocky Flats Plant The nearest educational facility is the Witt Elementary School, which is approximately 2 7 miles east of the Plant buffer zone The closest hospital is Centennial Peaks Hospital located approximately seven miles northeast. The closest park and recreational area is the Standley Lake area, which is approximately five miles southeast of the Plant. Boating, picnicking, and limited overnight camping are permitted Several other small parks exist in communities within ten miles The closest major park, Golden Gate Canyon State Park, located approximately 15 miles to the southwest, provides 8,400 acres of general camping and outdoor recreation Other national and state parks are located in the mountains west of the Rocky Flats Plant, but all are more than 15 miles away

Some of the land adjacent to the Plant is zoned for industrial development Industrial facilities within five miles include the TOSCO laboratory (40-acre site located two miles south), the Great Western Inorganics

Plant (two miles south), the Frontier Forest Products yard (two miles south), the Idealite Lightweight Aggregate Plant (2.4 miles northwest), and the Jefferson County Airport and Industrial Park (990-acre site located 4 8 miles northeast)

Several ranches are located within ten miles of the Plant, primarily in Jefferson and Boulder Counties. They are operated to produce crops, raise beef cattle, supply milk, and breed and train horses. According to the 1987 Colorado Agricultural Statistics, 20,758 acres of crops were planted in Jefferson County (total land area of approximately 475,000 acres) and 68,760 acres of crops were planted in Boulder County (total land area of 405,760 acres) Crops consisted of winter wheat, corn, barley, dry beans, sugar beets, hay, and oats Livestock consisted of 5,314 head of cattle, 113 hogs, and 346 sheep in Jefferson County, and 19,578 head of cattle, 2,216 hogs, and 12,133 sheep in Boulder County (Post, 1989)

1 3 2 6 Ecology

A variety of vegetation thrives within the Plant boundary Included are species of flora representative of tall-grass prairie, short-grass plains, lower montane, and foothill ravine regions None of these vegetative species are on the endangered species list. It is evident that the vegetative cover along the Front Range of the Rocky Mountains has been radically altered by human activities such as burning, timber cutting, road building, and overgrazing for many years Since the acquisition of the Rocky Flats Plant property, vegetative recovery has occurred, as evidenced by the presence of disturbance-sensitive grasses species like big bluestem (Andropogon gerardii) and sideoats grama (Bouteloua curtipendula) No vegetative stresses attributable to hazardous waste contamination have been identified (U S DOE, 1980)

The animal life inhabiting the Rocky Flats Plant and its buffer zone consists of species associated with western prairie regions The most common large mammal is the mule deer (Odocoileus lemionus), with an estimated 100 to 125 permanent residents. There are a number of small carnivores, such as the coyote (Canis latrans), red fox (Vulpes fulva), striped skunk (Mephitis mephitis), and long-tailed weasel (Mustela frenata) A profusion of small herbivores consisting of species such as the pocket gopher (Thomomys sp and Perognathus sp), white-tailed jackrabbit (Lepus townsendii), and the meadow vole (Microtus pennsylvanicus) can be found throughout the Plant and buffer zone (U S DOE, 1980)

Commonly observed birds include western meadowlarks (Sturnella neglecta), horned larks (Eremophila alpestris), mourning doves (Zenaidura macroura), and vesper sparrow (Pooecetes gramineus) A variety of ducks, killdeer (Charadrius vociferus), and red-winged black birds (Agelaius phoeniceus) are seen in areas adjacent to ponds. Mallards (Anas platyrhynochos) and other ducks (Anas sp) frequently nest and rear young on several of the ponds Common birds of prey in the area include marsh hawks (Circus cyaneus), red-tailed hawks (Buteo jamaicensis), ferruginous hawks (Buteo regalis), rough-legged hawk (Buteo lagopus), and great horned owls (Bubo virginianus) (U S DOE, 1980)

Bull snakes (Pituophis melanoleucus) and rattlesnakes (Crotalus sp) are the most frequently observed reptiles Eastern yellow-bellied racers (Coluber constrictor) have also been seen The eastern short-horned lizard (Phrynosoma douglassi brevirostre) has been reported on the site, but these and other lizards are not commonly observed The western painted turtle (Chrysemys picta) and the western plains garter snake (Thamnophis radix) are found in and around many of the ponds (U S DOE, 1980)

The bald eagle and the black-footed ferret are the two endangered species which were identified as potentially present at Rocky Flats Plant by the U S Fish and Wildlife Service Bald eagles are occasional visitors to the area primarily during migration times However, eagle sightings are rare and little suitable habitat exists at the Plant. No bald eagle nests have been found on the Plant site Prairie dogs provide the food source and habitat for black-footed ferrets Since there are no prairie dog towns in or near the 881 Hillside Area, ferrets probably do not exist at Operable Unit No 1 Subsequent to a field visit on June 15, 1988, the U S Fish and Wildlife Service has concurred with these findings (Rockwell International, 1988c)

1 4 881 HILLSIDE SITE LOCATIONS AND DESCRIPTIONS

This RFI/RI Work Plan addresses the 881 Hillside Area located on the south side of the Rocky Flats Plant security area. These sites were designated high priority sites because of their suspected relationship to ground-water contamination (U S DOE, 1987a) Several sites are included in the area because of their physical proximity to each other Figure 1-5 shows the location of the 881 Hillside Area and presents the IHSS locations within the area

There are 12 sites designated as IHSSs located within Operable Unit No. 1 These sites are

- Oil Sludge Pit Site (IHSS Ref No 102),
- Chemical Burial Site (IHSS Ref No 103),
- Liquid Dumping Site (IHSS Ref No. 104),
- Out-of-service Fuel Oil Tank Sites (IHSS Ref Nos. 105 1 and 105 2),
- Outfall Site (IHSS Ref No 106),
- Hillside Oil Leak Site (IHSS Ref No 107),
- Multiple Solvent Spill Sites (IHSS Ref Nos. 119 1 and 119 2),
- Radioactive Site - 800 Area Site #1 (IHSS Ref No 130),
- Sanitary Waste Line Leak Site (IHSS Ref No 145), and
- Building 885 Drum Storage Site (IHSS Ref No 177)

The site descriptions presented in the following sections are taken from the Rocky Flats Plant CEARP Phase I Report (U S DOE, 1986), the RCRA Part B Operating Permit Application (Rockwell International, 1987c), and the Phase II Remedial Investigation Report for High Priority Sites (Rockwell International, 1988a) The following descriptions also include a more recent review of historical aerial photography

1 4 1 Oil Sludge Pit Site (IHSS Ref. No. 102)

Approximately 30 to 50 drums of oil sludge were emptied into a pit south of Building 881 in the late 1950s, and the pit was later covered (Rockwell International, 1987c) Based on interviews with Plant personnel, the sludge was reportedly collected during cleaning of the two No 6 fuel oil tanks south of Building 881 (IHSS Ref Nos 105 1 and 105 2) in 1958 (Rockwell International, 1987c) However, the pit appears to have been in existence in 1955 based on aerial photography of the area In the 1955 photos, the oil sludge pit is located approximately 500 feet south of Building 881 and measures approximately 40 feet by 70 feet in dimension The pit appears to contain oily liquids, and seepage from the pit is evident Also apparent on the 1955 photo is a small pond adjacent to Woman Creek. Drainage from the Oil Sludge Pit Site appears directed toward this pond The oil sludge pit was covered after its use (Rockwell International, 1987c), and the pit and seepage are no longer visible on 1959 aerial photographs.

1 4 2 Chemical Burial Site (IHSS Ref. No. 103)

An area south of Building 881 was reportedly used to bury unknown chemicals (U S DOE, 1986) The exact location, dates of use, and contents of the site are unknown This site was originally thought to be located in the same area as the Oil Sludge Pit Site (Rockwell International, 1987c) However, a pit apparently filled with liquid is evident approximately 150 feet southeast of Building 881 on 1963 aerial photographs This pit is roughly circular on the photos and measures approximately 50 feet in diameter

1 4 3 Liquid Dumping Site (IHSS Ref No. 104)

An area east of Building 881 was reportedly used for disposal of unknown liquids and for disposing empty drums prior to 1969 (U S DOE, 1986) A pit was reported with plan dimensions of approximately 50 by 50 feet based on 1965 aerial photographs (Rockwell International, 1987c) However, further review of these historical aerial photos indicates the identified "pit" may be a shadow on the photo The Liquid Dumping Pit Site is likely the same location as the Chemical Burial Site, however, the area originally identified as the Liquid Dumping Pit will also undergo additional investigation to verify its absence

1 4 4 Out-of Service Fuel Tank Sites (IHSS Ref Nos 105.1 and 105.2)

Two out-of-service No 6 fuel oil tanks are located immediately south of Building 881 (Figure 1-6) These tanks were used from 1958 through 1976 They were filled with asbestos-containing material and then with concrete subsequent to their use (presumably in 1976), (Rockwell International, 1987c) These tanks tested tight when they were pressure tested in 1973 (Rockwell International, 1987c)

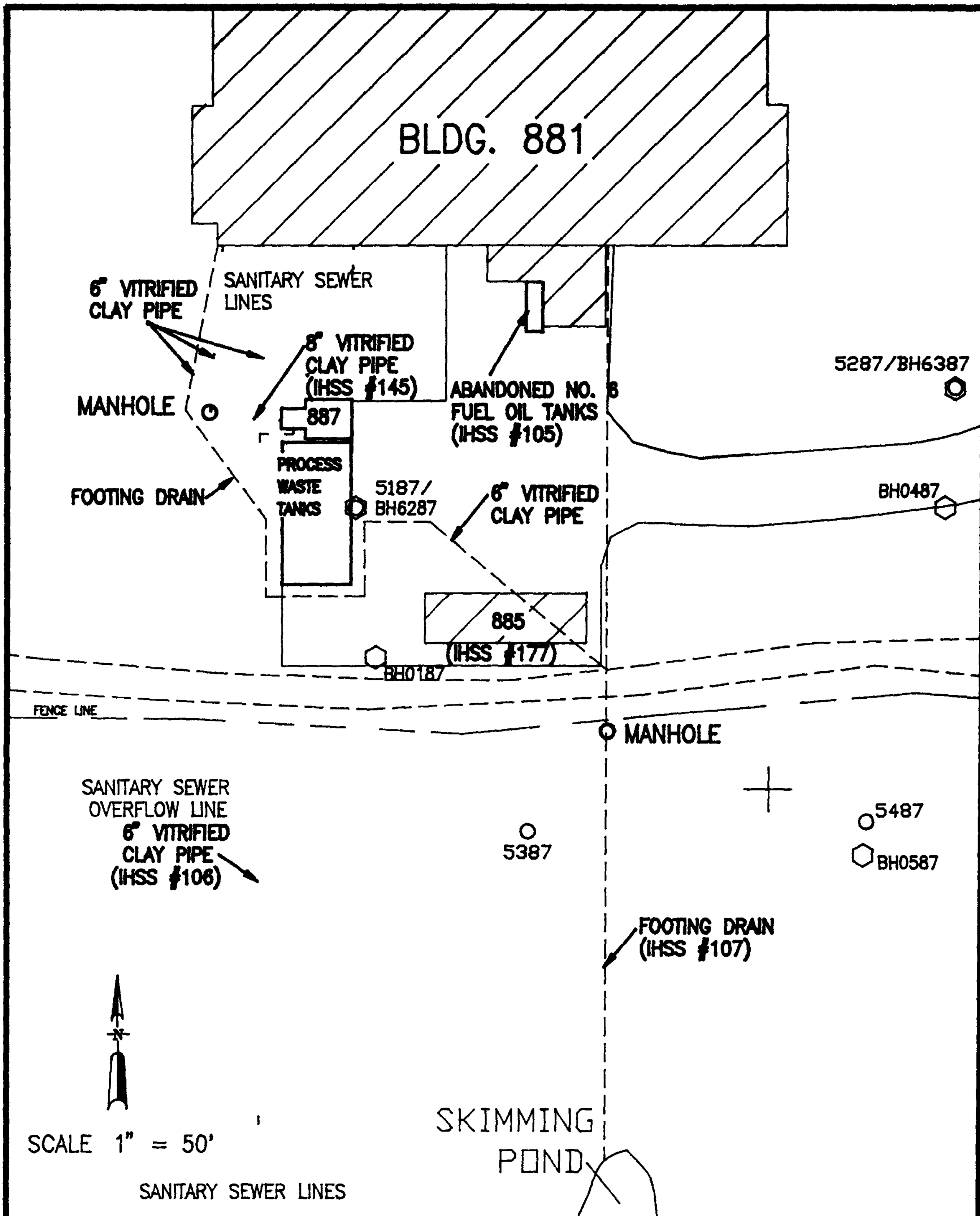

FIGURE 1-6
ENLARGEMENT OF IHSS'S 105,106,107,145, AND 177

881016/50.pj-100990

1 4 5 Outfall Site (IHSS Ref. No. 106)

A six-inch diameter vitrified clay pipe outfall existed south of Building 881 which discharged water in December 1977 Previous reports indicated that this was a cleanout pipe for an overflow line from the Building 881 cooling tower (Rockwell International, 1987c) However, review of construction drawings during the Phase II RI indicated that the pipe is an overflow line from the sanitary sewer sump in Building 887 (Figure 1-6)

1 4 6 Hillside Oil Leak Site (IHSS Ref. No. 107)

In May 1973, an oil leak was discovered on the hillside south of Building 881 The source of the oil was believed to be the two No 6 fuel oil tanks (IHSSs 105 1 and 105 2) south of the building, however, pressure testing of the tanks and associated lines in 1973 did not reveal any leaks (Rockwell International, 1987c) The oil spill was contained with straw, and the straw and soil were removed and disposed of in the Present Landfill north of the Plant (Rockwell International, 1987c)

It was later discovered that the oil had emerged through the Building 881 footing drain outfall (Figure 1-6) A ditch and concrete skimming pond were built below the footing drain outfall to contain the oil (Owen and Steward, 1973) These structures are still present, although no oil has been observed in the outfall since 1973 (Rockwell International, 1987c)

1 4 7 Multiple Solvent Spill Site (IHSS Ref. Nos. 119.1 and 119.2)

Beginning in 1967, two areas east of Building 881 and along the southern perimeter road were used as barrel storage areas The barrels contained unknown quantities and types of solvents and wastes The two facilities were expanded between 1967 and 1971, with major expansion occurring in 1969 Barrel storage in these areas was discontinued, and all barrels were removed by 1972 The exact types and quantities of solvents stored at this facility are unknown (Rockwell International, 1987c) IHSS 119 1 is the larger western barrel storage area, and IHSS 119 2 is the eastern barrel storage area The site boundaries shown on Figure

1-5 represent the extent of soil disturbance associated with the sites. Actual barrel storage areas within each site are also shown.

1 4 8 Radioactive Site - 800 Area #1 (IHSS Ref. No. 130)

An area east of Building 881 and northwest of IHSS 119 1 was used between 1969 and 1972 to dispose of soil and asphalt contaminated with low levels of plutonium The materials at this site were derived from three sources on the Plant site

In September 1969 approximately 320 tons [250 cubic yards (Illsley, 1978)] of plutonium-contaminated soil and asphalt were removed from the west side of Building 776 and placed on the 881 Hillside (Owen and Steward, 1973) The soil and asphalt were contaminated during the May 11, 1969, fire in building 776, and had an estimated average plutonium activity of 7 4 disintegrations per minute per gram (dpm/g) [3 36 picoCuries per gram (pCi/g)] The total plutonium concentration of this material was estimated to be 14 milligrams (mg) [864 microCuries (μCi)] (Putzier, 1970) Material from the 1969 fire was buried under one to two feet of fill dirt (Owen and Steward, 1973)

In August 1970, a section of the Central Avenue roadway between Eighth and Tenth Streets was removed and placed on the 881 Hillside at IHSS 130 (Owen and Steward, 1973) This stretch of road was radioactively contaminated in June 1968 by a leaking drum in transit from the 903 Drum Storage Site to Building 774 (Owen and Steward, 1973) The exact quantity and radioactivity of the material removed from Central Avenue are unknown

The third episode of soil disposal at IHSS 130 occurred in 1972 (Owen and Steward, 1973) Approximately 60 cubic yards of plutonium-contaminated soil were removed from around the Building 774 process waste tanks and placed on the 881 Hillside (Owen and Steward, 1973) The soil was placed on top of previously deposited soils at IHSS 130 and covered with approximately three feet of fill dirt (Illsley, 1978) The estimated total long-lived alpha activity of this soil is less than 250 dpm/g (Illsley, 1978)

1 4 9 Sanitary Waste Line Leak Site (IHSS Ref. No. 145)

The four-inch, cement-asbestos sanitary sewer line located south of Building 881 leaked in January 1981 An earthen dike was constructed to prevent the spill from entering the South Interceptor Ditch, and the line was repaired The line conveyed sanitary wastes to the sanitary treatment plant and did not carry hazardous or radioactive materials Conveyance of laundry wastewater, which may have contained low levels of radioactive materials, was discontinued in 1973 (Rockwell International, 1987c) Recent review of Building 881 construction drawings indicates that the only sanitary waste lines presently located south of the building are the six-inch overflow line from Building 887 (IHSS 106) and an eight-inch vitrified clay pipe which runs east-west into Building 887 (Figure 1-6) Presumably, the four-inch, cement-asbestos sewer line was replaced subsequent to the waste line leak

1 4 10 Building 885 Drum Storage Site (IHSS Ref No. 177)

Building 885, immediately south of Building 881, is currently used for satellite collection and 90-day accumulation of RCRA regulated wastes (Figure 1-6) The building will be closed under RCRA Interim Status (40 CFR 265) Complete information on this site is provided in the RCRA Interim Status Closure Plan which is appended to the revised Post-Closure Care Permit Application for hazardous and radioactive mixed wastes at the Rocky Flats Plant (Rockwell International, 1988d) Any ground-water contamination from this site will be addressed by the remedial action for Operable Unit No 1

SECTION 2

PHASE I AND PHASE II SITE EVALUATION

2.1 881 HILLSIDE AREA PREVIOUS INVESTIGATIONS

Remedial investigations were performed in two phases at the 881 Hillside Area The first phase of investigations began in March 1987, in accordance with the plans presented in U S DOE (1987a and 1987b) The second phase of field work was performed subsequent to submittal of the draft 881 Hillside Area Phase I RI Report and meetings with CDH and EPA to plan further work based on Phase I results

Objectives of the remedial investigations were to

- Verify waste source locations,
- Characterize waste sources,
- Characterize site geology and hydrology,
- Determine the presence and extent of ground-water, surface water, and soil contamination,
- Provide data to estimate the potential for contaminant migration via the ground-water, surface water, and air pathways, and
- Support feasibility studies of alternative remedial actions

The Phase I and Phase II field programs consisted of

- Preparation of detailed topographic site maps,
- Radiometric and organic vapor screening surveys,
- Geophysical surveys using electromagnetometry, resistivity, magnetometry, and metal detection,
- Soil gas sampling using the Petrex method,
- Drilling, sampling, and chemical analyses of subsurface soils from 17 Phase I boreholes and 6 Phase II boreholes (Figure 2-1),
- Installation of 4 alluvial wells and 3 bedrock wells during Phase I drilling and 11 alluvial wells and 1 bedrock well during Phase II drilling (Figure 2-1),
- Packer testing of cored bedrock wells,
- Slug testing on all new wells containing sufficient water for testing,

- **Single hole pumping tests of wells 2-87 and 4-87,**
- **Quarterly sampling and analysis of ground water from all 1986 wells (up to five quarters of data) and 1987 wells (in general, two samples for Phase I wells and one sample for Phase II wells) in the study area in addition to older wells which had shown contamination in the past,**
- **Surface water sampling and analysis from stations along Woman Creek and the South Interceptor Ditch, as well as from seeps and springs located in the area, and**
- **Bedload sediment sampling and analysis in Woman Creek**

In addition to the RI activities at the 881 Hillside Area, several monitor wells were installed as part of a Plant-wide hydrogeologic investigation in 1986 (Rockwell International, 1986e) Surface water, soil, and air samples have also been collected at these areas as part of various investigations, ground-water sampling has been conducted in the area on a quarterly basis since the Phase II RI, and surface water sampling was conducted monthly in 1989 Section 2 2 presents results of the previous RIs and a brief characterization of each contaminant migration pathway at the 881 Hillside Area The nature and extent of contamination associated with these pathways is discussed in Section 2 3 Section 3 discusses the need for and objectives of the Phase III RFI/RI

2 2 SITE CONCEPTUAL MODEL

A site-specific conceptual model of the 881 Hillside Area has been developed based on previous investigations This model describes contaminant sources and pathways through which contaminant transport may occur from these areas

2 2 1 Geology

2 2 1 1 Surficial Geology

Surficial materials at the 881 Hillside Area consist of the Rocky Flats Alluvium, colluvium, valley fill alluvium, and artificial fill unconformably overlying bedrock In addition, there are a few isolated exposures of claystone bedrock Figure 2-2 presents the distribution of surficial materials The study area is located on the south-facing hillside which slopes down from the Rocky Flats terrace toward Woman Creek on the south side of the Plant Rocky Flats Alluvium caps the top of the slope, and colluvium covers the hillside Artificial fill and disturbed surficial materials are present around Building 881 and south of the building to the South Interceptor Ditch Artificial fill overlies colluvium at IHSS 130, and surficial materials are disturbed in the vicinity of IHSSs 119 1 and 119 2 Valley fill alluvium is present along the drainage of Woman Creek south of the 881 Hillside Area, and terrace alluvium occurs on the north side of the Woman Creek valley fill alluvium

Rocky Flats Alluvium

The Quaternary Rocky Flats Alluvium is the oldest and topographically highest alluvial deposit at the Rocky Flats Plant (Scott, 1965) The Rocky Flats Alluvium is a series of coalescing alluvial fans deposited by braided streams (Hurr, 1976) The erosional surface (pediment) on which the alluvium was deposited slopes gently eastward truncating the Fox Hills Sandstone, the Laramie Formation, and the Arapahoe Formation at the Rocky Flats Plant

After deposition of the Rocky Flats Alluvium, eastward flowing streams began dissecting the deposit by headward erosion and lateral planation All of the alluvium was removed by erosion in the Woman Creek drainage south of the 881 Hillside Area and in the South Walnut Creek drainage to the north The result is a terrace of Rocky Flats Alluvium extending eastward from the Plant between the two drainages This terrace forms the crest of the 881 Hillside Area

Colluvium

Colluvial materials are present on the hillside below the Rocky Flats terrace east of Building 881 and extend south to the Woman Creek drainage (Figure 2-2) These materials are deposited by slope wash and downslope creep of Rocky Flats Alluvium and bedrock Colluvium ranges from two feet (BH16-87) to twenty-two (well 62-86) feet in thickness

Colluvial materials on the 881 Hillside have been disturbed by construction of Building 881, various excavation activities associated with the IHSSs, and construction of the South Interceptor Ditch These areas are shown as disturbed ground on Figure 2-2 Within IHSSs 119 1 and 119 2, shallow excavation took place to construct roadways and to provide level drum storage areas Colluvium is also disturbed south of Building

881 in the vicinity of IHSSs 106 and 107 This area was excavated during construction of the skimming pond in 1972 Finally, colluvium was excavated along the South Interceptor Ditch during its construction from 1979 to 1981

Colluvium is undisturbed on the hillside south of IHSSs 130, 119 1, and 119 2 and south of the perimeter road The colluvium is thickest in the north-south trending swales draining the 881 Hillside (wells 4-87 and 6-87) and thinnest over the intervening ridges (wells 48-87, 49-87, and 50-87) Colluvium consists predominantly of clay with common occurrences of sandy clay and gravel layers

Gravel layers are present in colluvial materials both unconformably overlying bedrock and near the surface These gravels are likely deposited in a south (downslope) direction by creep and slope wash erosion of the Rocky Flats Alluvium and can be expected to be elongated in the north-south direction with a rather limited extent in the east-west direction The gravel layers range from 1 3 feet (wells 43-87, 62-86, and 69-86) to 5 5 feet (well 59-86) in thickness Colluvial gravel deposits can be correlated between some of the wells and boreholes For example, the basal gravel in well 59-86 can be traced to wells 69-86 and 8-87 Sand and gravel layers in well 43-87 can also be correlated with sand and gravel layers in well 4-87 (Figure 2-3)

Terrace Alluvium

A Quaternary terrace alluvium is present on the north side of the Woman Creek valley fill alluvium This terrace is approximately five to ten feet above the present stream level indicating that it is probably Holocene in age (Scott, 1960) The thickness of the deposit ranges from approximately three (well 58-86) to seven (well 55-87) feet The terrace alluvium is composed of very poorly sorted gravelly sand

Valley Fill Alluvium

The most recent alluvial deposit in the 881 Hillside Area is the valley fill alluvium along Woman Creek This alluvium is derived from reworked and redeposited older alluviums and bedrock Alluvium thickness ranges from approximately six feet (well 68-86) to nine feet (well 64-86) The unconsolidated valley fill alluvium consists of generally sorted, angular to subrounded granite and quartzite cobbles, pebbles, and gravels in a silty sand matrix.

Artificial Fill

There are two types of artificial fill on the 881 Hillside (Figure 2-2) derived from separate sources. The first is fill material derived from excavation of the Building 881 foundation, and the second is soil placed at IHSS 130 (Section 1 4 8)

Material excavated for the Building 881 foundation was spread over a large area generally south of the building The very poorly sorted and unconsolidated artificial fill was derived from Rocky Flat Alluvium, colluvium, and claystone bedrock It is predominantly composed of sandy clay with some gravelly zones

Soils placed at IHSS 130 comprise the second type of artificial fill It consists of clayey sand with subangular quartzite cobbles Asphalt was also encountered from 0 to 2 75 feet in BH11-87 The fill at IHSS 130 overlies natural colluvial materials In borehole BH11-87, approximately five feet of fill are present, with fill thickness increasing to approximately ten feet in BH10-87 The artificial fill at IHSS 130 was unsaturated during the Phase II RI drilling program

2 2 1 2 Bedrock Geology

The Cretaceous Arapahoe Formation underlies surficial materials at the 881 Hillside Area The bedrock beneath the 881 Hillside consists of claystones with interbedded lenticular sandstones, siltstones, and occasional minor lignite deposits The bedrock sediments were deposited by meandering and braided streams flowing generally from west to east off the Front Range (Weimer, 1973) Sandstones were deposited in stream channels and as overbank splays, claystones were deposited in back swamp and floodplain areas Leaf fossils, organic matter, and lignite beds were encountered within the claystones during drilling at the 881 Hillside Contacts between various lithologies are both gradational and sharp Based on preliminary results of the ongoing high resolution seismic reflection program at Rocky Flats Plant, bedrock in the 881 Hillside Area is dipping less than two degrees to the east. The seismic investigation along with the geologic characterization provide strong evidence that some sandstones at the Plant are quite continuous. Further determination of the sandstones' extent is necessary

Claystones

Arapahoe Formation claystone was the most frequently encountered lithology immediately below the alluvium/bedrock contact. Claystones are generally thinly bedded and contain occasional laminae and interbeds of fine-grained sand and silt (wells 3-87, 45-87, and 47-87) Intervals of carbonaceous material and fossils (mainly plant fragments and leaves) are also common in the claystones.

Weathered bedrock was encountered directly beneath surficial materials in all of the boreholes and wells, and weathering appears to penetrate between approximately two (borehole BH16-87) and 60 feet (well 62-86) into bedrock Claystone in the weathered zone are generally consolidated and exhibit blocky structure, while sandstones in the weathered zone are typically friable Iron oxide staining and concretions along with caliche are characteristic of the zone The weathered claystone is also characterized by mild fracturing and slightly higher hydraulic conductivities than unweathered claystone In well 5-87 and abandoned hole 7-87A, claystone was mildly fractured from the alluvium/ bedrock contact to depths of approximately 46 and 26 feet, respectively A 45 degree fracture was also identified in weathered claystone in well 8-87 at a depth of approximately 54 feet. The geometric mean of hydraulic conductivities based on three packer tests in well 5-87 was 7×10^{-7} centimeters per second (cm/s) or 0 7 feet per year (ft/yr) The range for that well was 2×10^{-7} cm/s to 2×10^{-6} cm/s A packer test in weathered claystone in well 8-87 also yielded a hydraulic conductivity value of 7×10^{-7} cm/s

Unweathered bedrock occurs between 37 7 (well 8-87) and 56 feet (well 3-87) below ground surface The unweathered claystones are typically darker gray than weathered claystone and have little mottling They are also more consolidated than weathered claystones and exhibit little to no fracturing The geometric mean hydraulic conductivity of unweathered claystones beneath the 881 Hillside is 1×10^{-7} cm/s, or 0 26 ft/yr based on packer tests in wells 3-87, 8-87, and 45-87

Sandstones

Arapahoe Formation sandstones were encountered beneath the 881 Hillside in holes 59-86, 62-86, 3-87, 5-87, 6-87A, 7-87A, 8-87, and 45-87 These sandstones are generally composed of well sorted, subrounded to rounded, very fine- to medium-grained, poorly to moderately well cemented quartz sand with up to 10% lithic fragments The thickness of individual sandstone beds ranged from approximately five feet (well 5-87) to twelve feet (well 8-87) The sandstone in well 45-87 (89.5 to 100 8 feet below ground surface) is generally thinly bedded and often contain laminae and interbeds of clay and silt (up to two inches thick in well 45-87)

Sandstones encountered in holes 5-87, 6-87A, 7-87A, and 8-87 are weathered Weathered sandstones ranged from olive gray to moderate yellowish brown in color with brown, orange, and yellow iron oxide staining Weathered sandstones were described as being friable and brittle Based on packer tests in well 5-87, weathered sandstone had a mean hydraulic conductivity of $3\,9 \times 10^{-7}$ cm/s. Unweathered sandstones are lithologically similar to the weathered sandstones and were found in wells 45-87 and 3-87, at 89 5 feet and 103 feet, respectively Unweathered sandstones are generally medium dark gray to pale olive in color with infrequent staining of brown and yellows The deeper unweathered sandstones are generally more consolidated than weathered sandstone Based on packer tests in well 3-87, unweathered sandstones had a mean hydraulic conductivity of $1\,2 \times 10^{-7}$ cm/sec The orientation, geometry, and extent of bedrock sandstones at the 881 Hillside are not well defined at this time A high resolution seismic reflection program and a Plant-wide geologic characterization are ongoing to better characterize bedrock stratigraphy

A saturated lignite bed was encountered from approximately 85 to 88 feet below ground surface in well 8-87 and between approximately 87 8 to 88 1 feet below ground surface in well 3-87 Very carbonaceous-rich claystones occur frequently in this stratigraphic horizon Based on a two degree dip of the bedrock, the two lignite layers correlate and are presumably continuous

2 2 2 Hydrogeology

Unconfined ground-water flow occurs in surficial materials and subcropping sandstones In addition, subcropping claystone may be saturated in some locations Confined ground-water flow occurs in deeper sandstone units

2.2.2.1 Unconfined Flow System

Ground water is present in the Rocky Flats Alluvium, colluvium, valley fill alluvium, and subcropping sandstones under unconfined conditions Recharge to the water table occurs as infiltration of incident precipitation and as seepage from ditches and creeks. In addition, retention ponds along Woman Creek likely recharge the valley fill alluvium.

The shallow ground-water flow system is quite dynamic, with large water level changes occurring in response to precipitation events and stream and ditch flow Alluvial water levels are highest during the spring and early summer months of May and June Water levels decline during late summer and fall, and some wells go dry at this time of year

There is a strong downward gradient between ground water in surficial materials and bedrock Vertical gradient data are provided in the RI report (Rockwell International, 1988a) Calculated vertical gradients ranging from about 0 3 to 2 ft/ft indicate a hydraulic potential for downward flow

Ground-Water Flow Directions

Figures 2-4, 2-5, 2-6, and 2-7 depict the water table in surficial materials in January, May, August, and October 1989, respectively Ground water flows from the Rocky Flats Alluvium at the top of the 881 Hillside generally southeast through colluvial materials toward Woman Creek At the Rocky Flats pediment edges, ground water emerges as seeps and springs at the contact between the alluvium and claystone bedrock (contact seeps), is consumed by evapotranspiration, or flows through colluvial materials following topography toward the valley fill and terrace alluviums Flow through colluvial materials appears to primarily occur in the gravel within the colluvium Available water level data for well 47-87 indicate that ground water is below the base of the South Interceptor Ditch (Figure 2-3), although there could be discharge to the ditch during wet periods Once ground water reaches the valley, it either flows down-valley in the alluvium (easterly), is consumed by evapotranspiration, or discharges to Woman Creek During the driest portions of the year, evapotranspiration can result in no flow in either the colluvium or the valley fill alluvium

Ground-water Flow Rates

Hydraulic conductivity values were calculated for surficial materials based on results of drawdown-recovery tests performed on 1986 wells during the initial site characterization (Rockwell International, 1986e) and on results of baildown/recovery and single well pumping tests performed on select 1986 and 1987 wells during remedial investigations (Rockwell International, 1987a, 1988a, and 1989a)

Hydraulic conductivity values are available for three wells completed in colluvium at the 881 Hillside, two are completed in gravel layers (wells 69-86 and 4-87) and one is completed in sandy clay (well 2-87) The test results indicate hydraulic conductivities of 9×10^{-4} cm/s and 7×10^{-5} cm/s for the gravel layers and 4×10^{-5} cm/s for the sandy clay Using the maximum hydraulic conductivity value of 9×10^{-4} cm/s, a gradient of 0 15 for colluvial materials at the hillside, and an assumed effective porosity of 0 1, the maximum possible ground-water velocity through colluvial materials is approximately 1,400 ft/yr Using the geometric mean hydraulic conductivity of 1×10^{-4} cm/s, a gradient of 0 15, and an effective porosity of 0 1, the mean ground-water velocity through colluvium is approximately 155 ft/yr Volatile organic contaminants from IHSSs 119 1 and 130, based on chemical data presented in Section 2 3, have not yet reached well 47-87 due to attenuation mechanisms in the area (That well was usually dry, but the samples that were obtained did not contain volatile organic concentrations above detection limit) Those data will be verified in Phase III, but current evidence suggests that organic contaminants in ground water from IHSS 119 1 have moved less than 200 feet in 15 to 18 years (11 to 13 ft/yr) This represents an estimate of organic contaminant migration rate, including the effects of retardation and attenuation, not ground-water flow rate There is one report of PCE [8J $\mu g/\ell$ - estimated below detection limit and flagged "A" (accepted with qualifications)] at well 64-86 That is insufficient to demonstrate contamination at that easterly location

Once ground water reaches the creek drainage, it travels within the alluvium east toward the property boundary at Indiana Street Flow in the alluvium occurs in response to infiltration events, and the saturated thickness decreases following the event by down-valley flow and evapotranspiration High evaporative losses have been noted repeatedly in investigations of the valley fill alluvium Hurr (1976) notes that as much as 0 25 cubic feet per second were lost to evapotranspiration along Woman Creek during the period July to September, 1974 In addition, both Rockwell International (1987c) and the DOE (1980) comment on evapotranspirative losses from the valley fill alluvium, based on water level records.

Based on evaluation of slug and drawdown/recovery tests, the Woman Creek valley fill alluvium has a geometric mean hydraulic conductivity of 1 5 x 10^{-3} cm/s (1,035 ft/yr) and a maximum conductivity of 3 x 10^{-3} cm/s (3,100 ft/yr) A hydraulic gradient of 0 021 was estimated from the grade of the alluvium base, and an assumed effective porosity of 0 1 was used to calculate flow velocity The resulting ground-water flow velocity ranges from 326 to 650 ft/yr using the geometric mean and maximum hydraulic conductivity values.

The inference that the ground water flows only three quarters of the year is based on water level data from wells completed in Woman Creek alluvium Six of the nine wells completed in the Woman Creek alluvium have been dry during at least some portion of the year since their installation The Phase II RI report (Rockwell International, 1988a) presents water level data which show that the valley fill alluvium is dry at wells 1-86, 64-86, and 66-86 from about June to October (three months) Because the alluvium is not saturated for the full year, a dissolved constituent travels only a portion of this distance each year Thus, a solute particle would travel approximately 160 to 490 feet in valley fill alluvium during a year based on the average and maximum hydraulic conductivity values Section 5 discusses additional hydraulic testing to estimate hydraulic conductivities as well as dispersion coefficients

2 2 2 2 Confined Ground-water Flow System

The greatest potential for ground-water flow in the Arapahoe Formation occurs in the sandstones contained within the claystones Ground-water recharge to sandstones occurs as infiltration from alluvial ground water where sandstones subcrop beneath the alluvium and by leakage from claystones overlying the sandstones

Following Robson et al (1981a), flow within individual sandstones is assumed to be from west to east, but the geometry of the bedrock ground-water flow path is not fully understood at this time due to its dependence upon the continuity of the sandstones and their hydraulic interconnection Evaluation of the lateral extent and degree of interconnection of the sandstone units is a primary goal of an ongoing program of profiling the Arapahoe Formation through drilling and the high resolution seismic reflection studies.

Hydraulic conductivity values for sandstones were estimated from drawdown-recovery tests performed in 1986, slug tests performed in 1987, and packer tests performed in 1986 and 1987 (Rockwell International, 1988a) Drawdown-recovery test results for wells 59-86, 62-86, and 5-87 in weathered sandstone were 3×10^{-4} cm/s, 3×10^{-5} cm/s, and 7×10^{-5} cm/s with a geometric mean of 9×10^{-5} cm/s The variability of results for sandstones is reasonable given their variable silt content Slug and packer tests typically yielded lower hydraulic conductivity values sandstone in wells 62-86 and 5-87 had values of 6×10^{-6} cm/s to 7×10^{-5} cm/s based on slug tests, and sandstone in wells 3-87 and 5-87 had values of 2×10^{-7} cm/s and 1×10^{-6} cm/s based on packer tests

2 2 3 Surface Water Hydrology

2 2 3 1 Woman Creek

Woman Creek is located south of the 881 Hillside Area with its headwaters in largely undisturbed Rocky Flats Alluvium Runoff from the southern part of the Plant is collected in the South Interceptor Ditch located due north of the creek and delivered to Pond C-2 Pond C-1 (upstream of C-2) receives stream flow from Woman Creek The discharge from Pond C-1 is diverted around Pond C-2 into the Woman Creek channel downstream Water in Pond C-2 is discharged to Woman Creek in accordance with the Plant NPDES permit (discharge point 007)

Flow in Woman Creek and the South Interceptor Ditch is intermittent, appearing and disappearing along various reaches During the 1986 initial site characterization, measurable flow occurred at less than one-half of the ten stations located along Woman Creek and the South Interceptor Ditch (Rockwell International, 1986e) All recorded flows, measured at the time of quarterly sampling events, were less than ten gallons per minute During the 1986 and 1987 investigations, there was no surface flow in Woman Creek downstream of Pond C-2 The intermittent surface water flow observed for Woman Creek and the South Interceptor Ditch is indicative of frequent interaction with the shallow ground-water system

2.3 NATURE AND EXTENT OF CONTAMINATION

2 3 1 Background Characterization

In order to facilitate the interpretation of chemical results in non-background areas, a background characterization program has been implemented to define the spatial and temporal variability of naturally occurring constituents A plan was completed in January 1989 (Rockwell International, 1989c), field work was conducted, and a draft Background Geochemical Characterization Report was prepared and submitted to the regulatory agencies in December 1989 (Rockwell International, 1989d) The document summarizes the background data for ground water, surface water, sediments, and geologic materials, and identifies preliminary statistical boundaries of background variability Spatial variations in the chemistry of geologic materials and water were addressed by placing sample locations throughout background areas at the Plant The goal of evaluating temporal variations in water chemistry has not yet been achieved because at least two years of quarterly data are needed The draft report is undergoing revision by incorporation of additional analytical data, however, the information in the draft Background Geochemical Report has been used to preliminarily characterize inorganic contamination at the 881 Hillside Area. The revised report will also address evaluation of outliers and the method of determining tolerance intervals for radionuclides

The boundaries of background variability were quantified through the calculation of tolerance intervals assuming a normal distribution Assumptions and statistical analyses of the background tolerance intervals are presented in Rockwell International (1989d) The upper limit of the tolerance interval or the maximum detected value for each parameter analyzed in background ground-water, surface water, sediment, and geologic samples are provided in Tables 2-1 through 2-4, respectively Maximum detected values are provided where there were insufficient data to calculate tolerance intervals This condition resulted from either an insufficient number of samples, or an insufficient number of detectable concentrations for a given analyte Background samples were not analyzed for EPA Contract Laboratory Program (CLP) Target Compound List (TCL) organics, because the background areas are outside of potentially contaminated areas

To assess the presence of inorganic contamination at the 881 Hillside Area, site-specific chemical data are compared to the background tolerance intervals or the maximum detected value if a tolerance interval could

TABLE 2-1

BACKGROUND GROUND-WATER QUARTER 2 1989
TOLERANCE INTERVAL UPPER LIMITS
MAXIMUM DETECTED VALUE

Analyte	Units	Rocky Flats Alluvium (11 Samples)	Colluvium (2 Samples)	Valley Fill Alluvium (8 Samples)	Weathered Claystone (4 Samples)	Weathered Sandstone (2 Samples)	Unweathered Sandstone (7 Samples)
<u>Dissolved Metals</u>							
Aluminum	mg/l	ND	ND	ND	ND	ND	0.327*
Antimony	mg/l	ND	ND	ND	ND	ND	ND
Arsenic	mg/l	ND	ND	ND	ND	ND	0.0186*
Barium	mg/l	ND	ND	ND	ND	ND	ND
Beryllium	mg/l	ND	ND	ND	ND	ND	ND
Cadmium	mg/l	ND	ND	ND	ND	ND	ND
Calcium	mg/l	85	76 8*	138	73 4*	65 7*	64.6
Cesium	mg/l	ND	ND	ND	ND	ND	ND
Chromium	mg/l	ND	ND	ND	ND	0 0122*	ND
Cobalt	mg/l	ND	ND	ND	ND	ND	ND
Copper	mg/l	ND	ND	ND	ND	ND	ND
Iron	mg/l	0.266*	ND	0 94*	ND	ND	ND
Lead	mg/l	ND	ND	ND	ND	ND	ND
Lithium	mg/l	ND	0 172*	0 028	031*	0 0106*	ND
Magnesium	mg/l	5.79*	15.3*	26 57	45 3*	9 41*	ND
Manganese	mg/l	0.365	0 088*	0 686*	0 126*	0.292*	0.0182*
Mercury	mg/l	ND	ND	0 003*	008*	ND	ND
Molybdenum	mg/l	0.0136*	ND	ND	0 015*	0 015*	0.112*
Nickel	mg/l	0 0432*	ND	ND	ND	ND	ND
Potassium	mg/l	7 73*	ND	ND	ND	ND	21.89*
Selenium	mg/l	ND	ND	0 0114*	ND	ND	0.041*
Silver	mg/l	ND	ND	ND	ND	ND	ND
Sodium	mg/l	13 4	98 7*	88	36 9*	25 6*	599
Strontium	mg/l	0 159*	ND	ND	ND	ND	0 451*
Thallium	mg/l	ND	ND	ND	0 01*	ND	ND
Tin	mg/l	ND	ND	ND	ND	ND	
Vanadium	mg/l	ND	ND	ND	ND	ND	ND
Zinc	mg/l	0 141*	ND	0 0212*	0 107*	ND	0.564

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TABLE 2-1 (cont.)

BACKGROUND GROUND-WATER QUARTER 2 1989
TOLERANCE INTERVAL UPPER LIMITS
MAXIMUM DETECTED VALUE

Analyte	Units	Rocky Flats Alluvium (11 Samples)	Colluvium (2 Samples)	Valley Fill Alluvium (8 Samples)	Weathered Claystone (4 Samples)	Weathered Sandstone (2 Samples)	Unweathered Sandstone (7 Samples)
Other							
Total Dissolved Solids	mg/l	352	520*	947	320*	170*	1761
Carbonate	mg/l	ND	ND	ND	ND	ND	49
Bicarbonate	mg/l	436	470*	719	400*	140*	412
Chloride	mg/l	15 6	20*	40 29	11*	15*	607
Sulfate	mg/l	45.1	86*	150	44*	16*	950
Nitrate	mg/l	2.98	0 18*	0 69*	0 58*	1 6*	0 610
Cyanide	mg/l	0038*	ND	ND	0 0036*	ND	ND
pH	----	8.6 (5.98)	7 4* (7 1)**	8 68 (6 12)	8 2* (7.4)**	7 5* (7 2)**	10 57 (7.43)
Dissolved Radionuclides							
Gross Alpha	pCi/l	12 543	27*	13 515	12*	7*	13*
Gross Beta	pCi/l	14.570	12*	18 530	7*	2*	15*
Uranium 233, 234	pCi/l	1.647	11*	6 481	5 8*	1.1*	12.936
Uranium 235	pCi/l	0 000	0.3*	0 232	0 2*	0*	0 135
Uranium 238	pCi/l	0.195	7 7*	5 084	3 2	0 6*	3 3507
Strontium 89, 90	pCi/l	0 552	0 1*	0 878	0 1	-0 1*	0 2*
Plutonium 239, 240	pCi/l	0 009	0*	0.012	0 03	0 01*	0.000
Americium 241	pCi/l	0.000	0*	0 012	0	0 01*	0.019
Cesium 137	pCi/l	0 603	0 2*	0 776	0 4	0 3*	0.7*
Tritium	pCi/l	309	100*	505	100	100*	731

* - Maximum Detected Value
** - Minimum Detected Value
ND - Not Detected at Contract Required Detection Limit
() - Tolerance Internal Lower Limit for Two-Sided Parameter

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TABLE 2-2

BACKGROUND SURFACE WATER (ROUND 1)
TOLERANCE INTERVAL UPPER LIMITS
OR MAXIMUM DETECTED VALUE

Analyte	Units	Round 1 (7 samples)** Total	Dissolved
Metals			
Aluminum	mg/l	0 916*	0 485*
Antimony	mg/l	ND	ND
Arsenic	mg/l	ND	ND
Barium	mg/l	ND	ND
Beryllium	mg/l	ND	ND
Cadmium	mg/l	ND	ND
Calcium	mg/l	85 01	85 92
Cesium	mg/l	1 00*	ND
Chromium	mg/l	ND	ND
Cobalt	mg/l	ND	ND
Copper	mg/l	ND	ND
Iron	mg/l	3 17	1 78*
Lead	mg/l	ND	0 006*
Lithium	mg/l	ND	ND
Magnesium	mg/l	12 48	12 82
Manganese	mg/l	0 636	0 368*
Mercury	mg/l	0 001	0 001
Molybdenum	mg/l	ND	ND
Nickel	mg/l	ND	ND
Potassium	mg/l	ND	ND
Selenium	mg/l	ND	ND
Silver	mg/l	0 001*	ND
Sodium	mg/l	47 36	46 22
Strontium	mg/l	0 382	0 40
Thallium	mg/l	ND	ND
Tin	mg/l	ND	ND
Vanadium	mg/l	ND	ND
Zinc	mg/l	0 027	0 032*

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TABLE 2-2 (cont.)

BACKGROUND SURFACE WATER (ROUND 1)
TOLERANCE INTERVAL UPPER LIMITS
OR MAXIMUM DETECTED VALUE

Analyte	Units	Round 1 (7 samples)** Total	Dissolved
Other			
Total Dissolved Solids	mg/l	271 16	NA
Carbonate	mg/l	ND	NA
Bicarbonate	mg/l	296 97	NA
Chloride	mg/l	106 9	NA
Sulfate	mg/l	48 82	NA
Nitrate	mg/l	2 69	NA
Cyanide	mg/l	ND	NA
pH	----	8 69 (6 60)	NA
Radionuclides			
Gross Alpha	pCi/l	7 74	4 38
Gross Beta	pCi/l	9 89	8 80
Uranium 233, 234	pCi/l	1 45	1 40
Uranium 235	pCi/l	0 133	0 133
Uranium 238	pCi/l	0 803	0 957
Strontium 89, 90	pCi/l	2 04	1 398
Plutonium 239, 240	pCi/l	0 018	ND
Americium 241	pCi/l	0 042	0 013
Cesium 137	pCi/l	0 599	0 472
Tritium	pCi/l	258	NA

NA - Not Analyzed
ND - Not Detected
() - Tolerance Interval Lower Limit for Two-Sided Parameter
* - Maximum Detected Value
** - At Stations SW-104 and SW-80, most total and a few dissolved constituents were uncharacteristically high relative to the other data To be conservative, these data are not included in computation of the tolerance interval

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TABLE 2-3

BACKGROUND SEDIMENT
TOLERANCE INTERVAL UPPER LIMITS
OR MAXIMUM DETECTED VALUE

Analyte	Units	Upper Limit (9 Samples)
Total Metals		
Aluminum	mg/l	24789
Antimony	mg/l	ND
Arsenic	mg/l	13 0*
Barium	mg/l	182*
Beryllium	mg/l	ND
Cadmium	mg/l	ND
Calcium	mg/l	72551
Cesium	mg/l	ND
Chromium	mg/l	43 38
Cobalt	mg/l	ND
Copper	mg/l	22 0*
Iron	mg/l	28308
Lead	mg/l	39 502
Lithium	mg/l	ND
Magnesium	mg/l	4110*
Manganese	mg/l	372 20
Mercury	mg/l	ND
Molybdenum	mg/l	ND
Nickel	mg/l	29 9*
Potassium	mg/l	ND
Selenium	mg/l	ND
Silver	mg/l	6 8*
Sodium	mg/l	ND
Strontium	mg/l	175*
Thallium	mg/l	ND
Tin	mg/l	ND
Vanadium	mg/l	50 2*
Zinc	mg/l	92 688

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TABLE 2-3 (cont.)

BACKGROUND SEDIMENT
TOLERANCE INTERVAL UPPER LIMITS
OR MAXIMUM DETECTED VALUE

Analyte	Units	Upper Limit (9 Samples)
Other		
Nitrate	mg/l	ND
pH	----	9 03 (8 77)
Total Radionuclides		
Gross Alpha	pCi/l	60
Gross Beta	pCi/l	50
Uranium 233, 234	pCi/l	1 669
Uranium 235	pCi/l	0 176
Uranium 238	pCi/l	1 755
Strontium 89, 90	pCi/l	1 390
Plutonium 239, 240	pCi/l	0.096
Americium 241	pCi/l	0 029
Cesium 137	pCi/l	1 578
Tritium	pCi/l	0 408

ND - Not Detected
* - Maximum Detected Value
() - Tolerance Interval Lower Limit for Two-Sided Parameter

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TABLE 2-4

BACKGROUND GEOLOGIC MATERIALS
TOLERANCE INTERVAL UPPER LIMITS
MAXIMUM DETECTED VALUE

Analyte	Units	Rocky Flats Alluvium (70 Samples)	Colluvium (28 Samples)	Weathered Claystone (17 Samples)	Weathered Sandstone (4 Samples)
Total Metals					
Aluminum	mg/l	25312	21663	13495	10300*
Antimony	mg/l	ND	ND	16 2*	ND
Arsenic	mg/l	15 86	7 7	15.05	3 6*
Barium	mg/l	155 8	345 8	240.1	165*
Beryllium	mg/l	11 27	17 75	11.8	2.2*
Cadmium	mg/l	3.2*	1 8*	ND	ND
Calcium	mg/l	43079	20811	10183	5940*
Cesium	mg/l	ND	274*	ND	ND
Chromium	mg/l	37.9	26.8	16 57	10 7*
Cobalt	mg/l	18.2*	15 9*	29.7*	20 5*
Copper	mg/l	20.03	26.7	30 62	19 6*
Iron	mg/l	22916	29991	41295	12300*
Lead	mg/l	18 04	26 4	34 5	13.4*
Lithium	mg/l	44.4	32 1	33 37	7.0*
Magnesium	mg/l	4425	6151	4896	2520*
Manganese	mg/l	422 9	545 1	656	305*
Mercury	mg/l	0 58*	0 44*	0 35*	0 27*
Molybdenum	mg/l	38 65	32 78	33 68	11 2*
Nickel	mg/l	43 27	35 4	56.95	14 3*
Potassium	mg/l	3336	2789	1400*	ND
Selenium	mg/l	ND	ND	ND	ND
Silver	mg/l	40 9*	33 5*	18 7*	12 7*
Sodium	mg/l	ND	3680*	ND	ND
Strontium	mg/l	226*	111 1	144 42	69 2*
Thallium	mg/l	ND	ND	ND	ND
Tin	mg/l	338*	441*	274*	268*
Vanadium	mg/l	54 67	58 2	47.7	22.2*
Zinc	mg/l	52 64	98 1	106 7	79 9*

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TABLE 2-4 (cont.)

BACKGROUND GEOLOGIC MATERIALS
TOLERANCE INTERVAL UPPER LIMITS
MAXIMUM DETECTED VALUE

Analyte	Units	Rocky Flats Alluvium (70 Samples)	Colluvium (28 Samples)	Weathered Claystone (17 Samples)	Weathered Sandstone (4 Samples)
<u>Other</u>					
Sulfide	mg/l	13*	5*	5*	2*
Nitrate	mg/l	4.3*	4 274	2.0*	1.9*
pH	----	9.64 (6 06)	9 48 (6.96)	10.14 (7.04)	9.2* (8.0)**
<u>Total Radionuclides</u>					
Gross Alpha	pCi/l	37.108	51 710	52.302	37
Gross Beta	pCi/l	36.886	35 135	35.743	29
Uranium 233, 234	pCi/l	1.491	1 759	1.985	0 8
Uranium 235	pCi/l	0.087	0 169	0 258	0.1
Uranium 238	pCi/l	1.353	1 675	1.643	1 0
Strontium 89, 90	pCi/l	0 768	0 776	0.786	0 4
Plutonium 239, 240	pCi/l	0.017	0 023	0.020	0 01
Americium 241	pCi/l	0 018	NR	NR	NR
Cesium 137	pCi/l	0.082	0 113	ND	0 0
Tritium	pCi/l	0 410	0 299	0.322	0.39

ND - Not Detected
NR - Data Not Received
* - Maximum Detected Value
** - Minimum Detected Value
() - Tolerance Interval Lower Limit for Two-Sided Parameter

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not be calculated A constituent concentration that is greater than the upper limit of the one-sided 95% tolerance interval at the 95% confidence level will be considered to preliminarily represent contamination. Although not statistically significant, site specific chemical concentrations above the maximum detected background value are considered a very preliminary indication of contamination in the following assessment.

2 3 2 Soils

Phases I and II of the RI for Operable Unit No 1 focused on source characterization of preliminarily identified past waste disposal sites Soil samples were collected from Rocky Flats Alluvium, colluvium, and weathered claystone in 1987 in order to characterize the IHSSs. Figure 2-1 shows Phase I and II RI borehole sampling locations These soil samples were analyzed for the parameters listed in Table 2-5 Table 2-6 lists 881 Hillside borehole sampling information including sample depths, material sampled, and target IHSSs. Soil sampling results are presented in Appendix A.

2 3 2 1 Volatile Organic Compounds

Volatile organics data for soils previously collected from the 881 Hillside Area have been rejected during the data validation process primarily due to inadequate sample size Although these data cannot be used to quantitatively determine the extent of volatile organics contamination in this area, they are summarized here because they provide a qualitative indication of the spatial distribution of organic contamination in the soils and the relative magnitude of the contamination Future analyses will provide quantitative data

Methylene chloride, acetone, and phthalates were generally ubiquitous contaminants in the 881 Hillside soil samples There has been considerable debate as to whether they are truly contaminants of the soils Although methylene chloride and acetone were in many of the laboratory blanks, the use of an inappropriately small sample aliquot for soil analysis prevents conclusions as to whether these organics are contaminants of the soil The phthalate contamination may have resulted from sample handling although no testing has been performed to verify this hypothesis, and some phthalate levels are high Other evidence that supports the contention of laboratory artifact includes the absence or infrequent occurrence of methylene chloride and acetone in ground water (these contaminants are very mobile and soluble), and the presence of phthalates in

TABLE 2-5

PHASE I AND PHASE II RI
SOURCE SAMPLING PARAMETERS
SOIL AND WASTE SAMPLES

METALS

Hazardous Substances List - Metals

- Aluminum
- Antimony
- Arsenic
- Barium
- Beryllium
- Cadmium
- Calcium
- Chromium
- Cobalt
- Copper
- Iron
- Lead
- Magnesium
- Manganese
- Mercury
- Nickel
- Potassium
- Selenium
- Silver
- Sodium
- Thallium
- Tin
- Vanadium
- Zinc

Other Metals

- Chromium (hexavalent)
- Chromium (trivalent)
- Lithium
- Strontium

ORGANICS

Hazardous Substances List -- Volatiles

- Chloromethane
- Bromomethane
- Vinyl Chloride
- Chloroethane
- Methylene Chloride
- Acetone
- Carbon Disulfide
- 1,1-Dichloroethene
- 1,1-Dichloroethane
- trans-1,2-Dichloroethene
- Chloroform
- 1,2-Dichloroethane
- 2-Butanone
- 1,1,1-Trichloroethane
- Carbon Tetrachloride
- Vinyl Acetate
- Bromodichloromethane
- 1,1,2,2-Tetrachloroethane
- 1,2-Dichloropropane
- trans-1,3-Dichloropropene
- Trichloroethene
- Dibromochloromethane
- 1,1,2-Trichloroethane
- Benzene
- cis-1,3-Dichloropropene

TABLE 2-5 (CONTINUED)

PHASE I AND PHASE II RI
SOURCE SAMPLING PARAMETERS
SOIL AND WASTE SAMPLES

ORGANICS (CONT.)

Hazardous Substances List - Volatiles (Continued)

- 2-Chloroethyl Vinyl Ether
- Bromoform
- 2-Hexanone
- 4-Methyl-2-pentanone
- Tetrachloroethene
- Toluene
- Chlorobenzene
- Ethyl Benzene
- Styrene
- Total Xylenes

Hazardous Substances List -- Semi-Volatiles

- N-Nitrosodimethylamine
- Phenol
- Aniline
- bis(2-Chloroethyl)ether
- 2-Chlorophenol
- 1,3-Dichlorobenzene
- 1,4-Dichlorobenzene
- Benzyl Alcohol
- 1,2-Dichlorobenzene
- 2-Methylphenol
- bis(2-Chloroisopropyl)ether
- 4-Methylphenol
- N-Nitroso-Dipropylamine
- Hexachloroethane
- Nitrobenzene
- Isophorone
- 2-Nitrophenol
- 2,4-Dimethylphenol
- Benzoic Acid
- bis(2-Chloroethoxy)methane
- 2,4-Dichlorophenol
- 1,2,4-Trichlorobenzene
- Naphtalene
- 4-Chloroaniline
- Hexachlorobutadiene
- 4-Chloro-3-methylphenol(para-chloro-meta-cresol)
- 2-Methylnaphthalene
- Hexachlorocyclopentadiene
- 2,4,6-Trichlorophenol
- 2,4,5-Trichlorophenol
- 2-Chloronaphthalene
- 2-Nitroaniline
- Dimethyl Phthalate
- Acenaphthylene
- 3-Nitroaniline
- Acenaphthene
- 2,4-Dinitrophenol
- 4-Nitrophenol
- Dibenzofuran
- 2,4-Dinitrotoluene
- 2,6-Dinitrotoluene
- Diethylphthalate
- 4-Chlorophenyl Phenyl ether
- Fluorene
- 4-Nitroaniline
- 4,6-Dinitro-2-methylphenol

TABLE 2-5 (CONTINUED)

PHASE I AND PHASE II RI
SOURCE SAMPLING PARAMETERS
SOIL AND WASTE SAMPLES

ORGANICS (CONT.)

Hazardous Substances List -- Semi-Volatiles (Continued)

- N-nitrosodiphenylamine
- 4-Bromophenyl Phenyl ether
- Hexachlorobenzene
- Pentachlorophenol
- Phenanthrene
- Anthracene
- Di-n-butylphthalate
- Fluoranthene
- Benzidine
- Pyrene
- Butyl Benzyl Phthalate
- 3,3'-Dichlorobenzidine
- Benzo(a)anthracene
- bis(2-ethylhexyl)phthalate
- Chrysene
- Di-n-octyl Phthalate
- Benzo(b)fluoranthene
- Benzo(k)fluoranthene
- Benzo(a)pyrene
- Indeno(1,2,3-cd)pyrene
- Dibenz(a,h)anthracene
- Benzo(g,h,i)perylene

Hazardous Substances List -- Pesticides/PCBS

- alpha-BHC
- beta-BHC
- delta-BHC
- gamma-BHC (Lindane)
- Heptachlor
- Aldrin
- Heptachlor Epoxide
- Endosulfan I
- Dieldrin
- 4,4'-DDE
- Endrin
- Endosulfan II
- 4,4'-DDD
- Endrin Aldehyde
- Endosulfan Sulfate
- 4,4'-DDT
- Endrin Ketone
- Methoxychlor
- Chlordane
- Toxaphene
- AROCLOR-1016
- AROCLOR-1221
- AROCLOR-1232
- AROCLOR-1242
- AROCLOR-1248
- AROCLOR-1254
- AROCLOR-1260

Other Organics

- Oil and Grease

TABLE 2-5 (CONTINUED)

PHASE I AND PHASE II RI
SOURCE SAMPLING PARAMETERS
SOIL AND WASTE SAMPLES

RADIONUCLIDES	
	Gross Alpha
	Gross Beta
	Uranium 233+234, 235 and 238
	Americium 241
	Plutonium 239+240
	Strontium 89 + 90
	Cesium 137
	Tritium
OTHER	
	pH

TABLE 2-6

BOREHOLE SAMPLE INFORMATION

881 HILLSIDE BOREHOLES

Borehole Number	SAMPLE INFORMATION Number	Date	Depth Increment (ft)	Sample Type	Material Sampled	IHSS No.
BH0187	BH018701WT	06/04/87	0 20 - 1 40	WT	AF	145
BH0187	BH018704WS	06/04/87	4 50 - 5 70	CT,DH	KACS	
BH0187	BH018710WS	06/04/87	10 00 - 11 50	BR,DH	KACS	
BH0287	BH02870012	05/27/87	0 00 - 11 80	CO,FS	QC	106, 107
BH0287	BH02871214	05/27/87	11 80 - 14 30	CO	QC	
BH0287	BH028714CT	05/27/87	12 00 - 14 30	CT	KACS	
BH0287	BH02871420	05/27/87	14 30 - 20.40	CO	KACS	
BH0287	BH028718BR	05/27/87	17 90 - 18 60	BR	KACS	
BH0387	BH03870009	05/19/87	0 00 - 8 75	CO	QC	130
BH0387	BH03870204	05/19/87	2 00 - 4 00	CO	QC	
BH0387	BH038702WT	05/19/87	2 45 - 3 90	WT	QC	
BH0387	BH038709CT	05/19/87	7 15 - 8 75	CT	QC	
BH0387	BH038712BR	05/19/87	11 75 - 13 25	BR	KACS	
BH0487	BH04870010	06/05/87	0 00 - 10 00	CO	AF	105.1, 105 2
BH0487	BH048710WT	06/05/87	10 30 - 12 80	WT	AF	
BH0487	BH048715CT	06/05/87	15 30 - 15 70	CT	AF	
BH0487	BH048719BR	06/05/87	19 30 - 20 30	BR	KACS	
BH0587	BH05870005	05/19/87	0 00 - 4 50	CO	QC	103, 107
BH0587	BH058705CT	05/19/87	2.00 - 4 50	CT	QC	
BH0587	BH058708BR	05/19/87	7 50 - 9 30	BR	KACS	
BH0687	BH06870010	05/20/87	0.00 - 10 00	CO	QC	102
BH0687	BH06871020	05/20/87	10 00 - 20 00	CO	QC	
BH0687	BH068726CT	05/20/87	24.10 - 25 50	CT	QC	
BH0687	BH068730BR	05/20/87	27 00 - 30 00	BR	KACS	

Sample Type Codes: BR - Bedrock; CO - Composite; CT - Contact; DH - Direct Hit; FS - Field Screen; WT - Water Table; QRF - Rocky Flats Alluvium; QC - Colluvium; KACS - Weathered Claystone; AF - Artificial Fill

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TABLE 2-6 (cont.)

BOREHOLE SAMPLE INFORMATION

881 HILLSIDE BOREHOLES

Borehole Number	SAMPLE INFORMATION Number	Date	Depth Increment (ft)	Sample Type	Material Sampled	IHSS No.
BH0787	BH078705CT	05/26/87	4 30 - 4 80	CT, FS	QC	104, 130
BH0787	BH07870510	05/26/87	5 00 - 10 00	CO	KACS	
BH0787	BH078708BR	05/26/87	7 80 - 9 68	BR	KACS	
BH0787	BH078710WS	05/26/87	9 68 - 10 35	FS	KACS	
BH0787	BH07871013	05/26/87	10 35 - 13 00	CO	KACS	
BH0887	BH08870007	06/03/87	0.00 - 6 10	CO	QC	119.1
BH0887	BH088707CT	06/03/87	6.10 - 7 00	CT	QC	
BH0887	BH088710BR	06/03/87	10 20 - 12.10	BR	KACS	
BH0987	BH09870010	05/29/87	0 00 - 10 00	CO	QC	119 1
BH0987	BH098706WT	05/29/87	6 03 - 6.60	WT	QC	
BH0987	BH098711CT	05/29/87	10.08 - 11 30	CT	QC	
BH0987	BH098714BR	05/29/87	14.30 - 14 75	BR	KACS	
BH1087	BH10980010	06/01/87	0.00 - 10.00	CO	AF	130
BH1087	BH10871020	06/01/87	10.00 - 18.95	CO	QC	
BH1087	BH108720CT	06/01/87	18.95 - 20 00	CT	QC	
BH1087	BH108723BR	06/01/87	23.00 - 25 40	BR	KACS	
BH1187	BH11870010	06/02/87	0 00 - 10 00	CO	AF/QC	130
BH1187	BH118711CT	06/02/87	8 70 - 10 70	CT,FS	QC	
BH1187	BH118714WT	06/02/87	13 90 - 17 00	WT,BR	KACS	
BH1287	BH128702CT	05/27/87	0 00 - 2 25	CT	QC	119 1
BH1287	BH128705BR	05/27/87	5 25 - 6 50	BR	KACS	

Sample Type Codes: BR - Bedrock CO - Composite CT - Contact DH - Direct Hit FS - Field Screen WT - Water Table
QRF - Rocky Flats Alluvium QC - Colluvium KACS - Weathered Claystone AF - Artificial Fill

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TABLE 2-6 (cont.)

BOREHOLE SAMPLE INFORMATION

881 HILLSIDE BOREHOLES

Borehole Number	SAMPLE INFORMATION Number	Date	Depth Increment (ft)	Sample Type	Material Sampled	IHSS No.
BH1387	BH13870010	05/29/87	0 00 - 10 10	CO	QC	130
BH1387	BH138711CT	05/29/87	10 10 - 11 56	CT,FS	QC	
BH1387	BH138714BR	05/29/87	14 56 - 16 20	BR	KACS	
BH1487	BH148703W1	05/28/87	2 00 - 2 90	DH	QC	119 1
BH1487	BH148706CT	05/28/87	5.50 - 6.50	CT	QC	
BH1487	BH148708W2	05/28/87	7.75 - 8.00	DH,BR	KACS	
BH1487	BH148709BR	05/28/87	6.50 - 9 00	BR	KACS	
BH1587	BH15870005	06/03/87	0 00 - 5 00	CO	QRF	119.1
BH1587	BH15870510	06/03/87	5 00 - 10 0	CO	QRF	
BH1587	BH158726BR	06/03/87	24 10 - 25 80	BR	KACS	
BH1687	BH168702CT	06/02/87	0.00 - 1 80	CT	QC	119 2
BH1687	BH16870206	06/02/87	2 00 - 6 00	CO	KACS	
BH1687	BH168706BR	06/02/87	6 00 - 6 50	BR	KACS	
BH1787	BH17870005	06/03/87	0.00 - 3 90	CO	QC	119.2
BH1787	BH178705CT	06/03/87	3 90 - 5.25	CT	QC	
BH1787	BH178708BR	06/03/87	8 25 - 8 70	BR	KACS	
BH1787	BH178708BR	06/03/87	8.7 - 9.5	BR	KACS	
BH5787	BH578704DH	10/07/87	4.00 - 5 80	DH	QC	119.1
BH5787	BH578708DH	10/07/87	8 00 - 10.00	DH	QC	
BH5787	BH578710UC	10/07/87	10 00 - 12 00	CT, DH	QC	
BH5787	BH578712CT	10/07/87	12 00 - 14 00	CT, DH	KACS	
BH5787	BH578714BR	10/08/87	14 00 - 16 00	BR, DH	KACS	
BH5787	BH578716DH	10/08/87	16 00 - 18 00	BR, DH	KACS	

Sample Type Codes: BR - Bedrock CO - Composite CT - Contact DH - Direct Hit FS - Field Screen WT - Water Table
QRF - Rocky Flats Alluvium QC - Colluvium KACS - Weathered Claystone AF - Artificial Fill

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TABLE 2-6 (cont.)

BOREHOLE SAMPLE INFORMATION

881 HILLSIDE BOREHOLES

Borehole Number	SAMPLE INFORMATION Number	Date	Depth Increment (ft)	Sample Type	Material Sampled	IHSS No.
BH5787	BH578718DH	10/08/87	18 00 - 20 00	BR, DH	KACS	119 1
BH5787	BH578720DH	10/08/87	20 00 - 22.00	BR, DH	KACS	
BH5787	BH578722DH	10/08/87	22 00 - 24.00	BR, DH	KACS	
BH5787	BH578724DH	10/08/87	24 00 - 26 00	BR, DH	KACS	
BH5787	BH578726DH	10/08/87	26 00 - 28.00	BR, DH	KACS	
BH5887	BH588700UC	10/08/87	0 00 - 1 70	CT, DH	QC	119.2
BH5887	BH588702CT	10/08/87	2.00 - 3.90	CT, DH	QC	
BH5887	BH588704BR	10/08/87	4.00 - 7 00	BR	KACS	
BH5987	BH598704UC	10/05/87	2.00 - 3 50	UC	QC	119 2
BH5987	BH598707CT	10/05/87	4.00 - 7 20	CT	KACS	
BH5987	BH598709BR	10/05/87	7 00 - 9 80	BR	KACS	
BH6187	BH618707DH	10/12/87	6 50 - 9 00	DH	QC	119 2
BH6187	BH618709CT	10/13/87	9 00 - 11.50	CT	KACS	
BH6187	BH618712BR	10/13/87	11 50 - 14 00	BR	KACS	
BH6287	BH62870008	10/21/87	0 00 - 8 00	CO	QC	105 1, 105 2
BH6287	BH628712CT	10/21/87	12 50 - 14.00	CT	KACS	
BH6287	BH628714BR	10/21/87	14 00 - 16 00	BR	KACS	
BH6387	BH63870008	10/16/87	0.00 - 8 00	CO	AR/QRF	
BH6387	BH638712DH	10/16/87	12 00 - 13.70	DH	QRF	105 1, 105 2
BH6387	BH638718UC	10/19/87	18 00 - 18 40	CT	QRF	
BH6387	BH638722CT	10/19/87	22 00 - 22 50	CT	KACS	
BH6387	BH638724BR	10/19/87	24 50 - 26 00	BR	KACS	

Sample Type Codes BR - Bedrock CO - Composite CT - Contact DH - Direct Hit FS - Field Screen WT - Water Table
QRF - Rocky Flats Alluvium QC - Colluvium KACS - Weathered Claystone AF - Artificial Fill

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contention of laboratory artifact includes the a practically every soil sample (not suggestive of contamination) The available data cannot prove or disprove laboratory contamination for these samples.

Volatile chlorinated hydrocarbon contamination is apparently not extensive It occurred in soils from only 3 of the 23 boreholes [BH01-87 (IHSSs 107 and 177), BH57-87 (IHSS 119 1), and BH58-87 (IHSS 119 2)] The highest concentrations detected were tetrachloroethene (PCE) at 190 micrograms per kilogram (µg/kg) in BH01-87, trichloroethene (TCE) at 150 µg/kg in BH57-87, and 1,1,1-trichoroethane (1,1,1-TCA) at 110 µg/kg in BH57-87 Much lower concentrations (below or near detection limit) were reported for BH14-87 (TCE), BH12-87 (PCE) and BH61-87 (1,1,1-TCA)

Boreholes will be drilled and samples collected from all IHSSs for organic analysis during the Phase III RFI/RI An objective of this program will be to determine whether methylene chloride, acetone, and phthalates are soil contaminants Other objectives include verification of IHSS locations, assessment of the vertical and horizontal distribution of organic contamination, and identification of maximum concentrations of contaminants in suspected "hot spots"

2 3 2 2 Metals

In general, metal concentrations in soil samples from Rocky Flats Alluvium, colluvium, and claystone were within background levels Trace metals which occurred above background in these three materials include antimony (3%), arsenic (30%), mercury (6%), cadmium (61%), manganese (1%), and barium (7%) Parentheses indicate the percent of the samples exceeding the background range The metal data do not demonstrate gradients away from specific IHSSs These generally low concentrations of metals above background and their random spatial distribution does not suggest these metals represent contaminants The metals which do exceed background are typically very close to the estimated background levels Arsenic and cadmium are possible exceptions, reaching maxima of 24 milligrams per kilogram (mg/kg) and 6 4 mg/kg, respectively

2.3.2.3 Radionuclides

Radionuclides are analyzed by counting sub-atomic particle emissions, which is a random function Since radioactive disintegration is a statistical process and therefore has a probability distribution, results are reported as a measured value with an associated two standard deviation propagated error term following the measured value Computation of tolerance intervals for radionuclides did not account for the error term associated with each datum. Techniques are under investigation to account for propagation of error resulting from computation For the purposes of this plan, the boundaries of the background variability for radionuclides will be the tolerance intervals as computed in the draft Background Geochemical Characterization Report Site radionuclide concentrations where the error term is larger than the measured value are below the minimum detectable activity (MDA) and are considered not statistically different from background Measured values which do exceed their associated counting errors are considered above background if they are greater than the upper limit of the tolerance interval Because this comparison does not account for the propagated error associated with the upper limit of the background tolerance interval, this yields conservative interpretation of the site data It is also noted that the upper limits of the tolerance intervals are similar in magnitude to the maximum concentration observed for the data set.

Table 2-7 presents the percent of samples for each radionuclide detected above background at the surface and in the subsurface However, samples were composited over varying depths so the reported values are not representative of a thin surface veneer alone Plutonium and americium were only detected above background in surface soils (the maximum concentrations of 0 91 $\pm$ 0 38 pCi/g and 0 15 $\pm$ 0 13 pCi/g, respectively, were diluted by compositing) This contamination is probably derived from the 903 Pad Area by wind dissemination of plutonium/americium contaminated dust More recently collected data for plutonium, uranium 238, and uranium 233 + 234 concentrations in surface scrape samples are presented in Table 2-8 (U S DOE, 1990c) Sample locations are shown in Figure 2-8 Plutonium concentrations were as high as 4 8 pCi/g in surface soils at the 881 Hillside Area These concentrations are typical of surface plutonium concentrations in this vicinity and to the east within the Plant boundary (Rockwell International, 1987b) High uranium concentrations occurred in Samples 16 through 19 Uranium which is used at the Rocky Flats Plant is depleted in uranium 233 and uranium 234, and therefore has a uranium 233 + 234 to uranium 238 activity ratio of less than one The ratio for natural uranium is greater than one The uranium isotope ratios for these

TABLE 2-7

PERCENT OF SOIL SAMPLES WITH RADIONUCLIDES ABOVE BACKGROUND

Radionuclide	Percent of Surface* Samples Above Background	Percent of Subsurface Samples Above Background
Uranium (Total)	6	6
Plutonium 239 + 240	11	0
Americium 241	6	0
Cesium 137	17	7
Tritium	6	3

*This tabulation represents a minimum number of samples that had radionuclides above background because the surface soil samples were composites of thick (up to several feet) upper intervals

TABLE 2-8

881 HILLSIDE 1988 SURFACE SCRAPE SAMPLING RESULTS

RADIONUCLIDE CONCENTRATION IN pCi/g

Sample No	Uranium 233 + 234	Uranium 238	Plutonium
881-1	0 56±0 26	0 6±0 15	4 3±0 5
881-2	0 78±0 26	0 86±0 15	2.4±0 2
881-3	0 82±0 26	0 91±0 15	4 8±0 5
881-4	1 0±0 3	0 97±0 2	0 18±0 006
881-5	0 86±0 26	0 88±0 15	0 59±0 008
881-6	1 5±0 3	5 5±0 5	2 2±0 2
881-7	0 74±0 26	0 75±0 15	0 63±0 09
881-8	0 86±0 26	0 82±0 15	1 8±0 2
881-9	3 1±0 3	1 0±0 2	0 47±0 006
881-10	1 1±0 3	0 98±0 2	3 5±0 4
881-11	1 0±0 3	1 3±0 2	2 6±0 3
881-12	0 93±0 26	1 4±0 2	0 4±0 06
881-13	0 94±0 26	1 3±0 2	0 16±0 06
881-14	1 1±0 3	1 0±0 2	3 0±0 4
881-15	2 0±0 3	1 5±0 16	0 01±0 06
881-16	50±190	1300±100	0 3±0 06
881-17	19±74	590±70	0 78±0 19
881-18	60±230	3000±300	0 42±0 08
881-19	10±740	550±60	0 09±0 06

Data from U S DOE, 1990b

surface soils indicate the uranium is depleted (low ratio) The contamination presumably resulted from drums that had leaked in the past or from past spills.

Referring again to Table 2-7, uranium, cesium, and tritium occur infrequently above background in both surface and subsurface samples. None of these results exceeded background by more than a factor of two above the upper tolerance interval, but the results do not represent the true surface concentrations because the samples were composited over depth The uranium 233 + 234 to uranium 238 activity ratios are greater than one for most of Samples 1-15 indicating the natural uranium, but Samples 6, 12, and 13 indicate possible mixing with depleted uranium.

An independent assessment of criticality safety at Rocky Flats Plant conducted by Scientech, Inc , found no evidence of a criticality at the Rocky Flats Plant (U S DOE, 1989) This study noted that the levels of cesium 137 activity in the Rocky Flats area are in the range of 0 3 to 0 6 pCi/g averaged over a soil depth of six centimeters based on a July 1989 aerial radiological survey of the Plant (U S DOE, 1989) These values are consistent with world-wide fallout levels, and there is no indication of cesium 137 deposition due to Rocky Flats Plant operations (U S DOE, 1989)

2 3 3 Ground Water

Ground water at the 881 Hillside occurs in surficial materials (Rocky Flats Alluvium, colluvium, valley fill alluvium), and in weathered and unweathered bedrock The most significant contamination is in surficial materials, but weathered bedrock is hydraulically connected to the surface materials and therefore part of the contaminated, unconfined flow system Unweathered bedrock is considered part of the confined system The discussion of ground-water quality addresses two groups of relatively closely-spaced IHSSs A western group includes IHSSs 102, 103, 105, 106, 107, 145, and 177 The eastern portion of the 881 Hillside includes IHSSs 119 1, 119 2 and 130

Eight monitor wells were completed in surficial materials downgradient of IHSSs 102, 103, 105, 106, 107, 145 and 177 (51-87, 52-87, 58-86, 69-86, 2-87, 53-87, 54-87 and 59-86R) Wells 1-87 and 68-86 were initially considered upgradient of these IHSSs, but water level and chemical data suggest that well 1-87 may be sidegradient. Ground-water quality in both of these wells is occasionally above background and may be affected by Plant activities upgradient of the 881 Hillside. Additional upgradient wells will be installed to investigate this possibility Three of the wells were dry at all sampling attempts (51-87, 54-87 and 58-86)

Fourteen monitor wells were completed in the surficial materials downgradient of IHSSs 119 1, 119 2 and 130 (9-74, 10-74, 64-86, 4-87, 5-87, 6-87, 43-87, 47-87, 48-87, 63-86, 44-87, 49-87, 50-87, and 55-87) Several of these wells show significant contamination. Ground-water levels in the last five were always too low to yield samples.

Three wells were completed in weathered sandstone (5-87, 62-86 and 59-86), and two were completed in unweathered sandstone (3-87 and 45-87) A third deep well (8-87) was completed in lignite (It is grouped with the unweathered sandstones in Appendix B)

All available data (fourth quarter 1986 through first quarter 1990) are considered in the following assessment which compares site data to the background ground-water quality tolerance intervals. However, background ground-water data are available only for the second quarter of 1989, so the discussion compares site and background data from different seasons Section 2 3 1 includes a more complete description of the background study and emphasizes that conclusions regarding ground-water quality are necessarily preliminary Ground-water samples were analyzed for the parameters listed in Table 2-9, and all available data are presented in Appendix B

2 3 3 1 Volatile Organic Compounds

Unconfined Ground Water

Several wells had detectable volatile organic compounds in the surficial materials over the course of sampling from late 1986 to 1990 Maximum values are shown in Table 2-10 Concentrations plotted in Figures 2-9 and 2-10 illustrate the general distribution that characterizes the organic contamination, although these maps specifically show only PCE and TCE in the second quarter of 1989 Of the wells that are marked "dry" on Figures 2-9 and 2-10, only three wells were dry throughout all sampling (wells 63-86, 44-87, and 49-87)

TABLE 2-9

PHASE I AND PHASE II RI
GROUND-WATER AND SURFACE WATER SAMPLING PARAMETERS

FIELD PARAMETERS

- pH
- Specific Conductance
- Temperature
- Dissolved Oxygen*

INDICATORS

- Total Dissolved Solids*
- Total Suspended Solids*

METALS**

- Hazardous Substances List - Metals
  - Aluminum
  - Antimony
  - Arsenic
  - Barium
  - Beryllium
  - Cadmium
  - Calcium
  - Chromium
  - Cobalt
  - Copper
  - Iron
  - Lead
  - Magnesium
  - Manganese
  - Mercury
  - Nickel
  - Potassium
  - Selenium
  - Silver
  - Sodium
  - Thallium
  - Tin
  - Vanadium
  - Zinc

- Other Metals
  - Chromium (hexavalent)
  - Lithium
  - Strontium

ANIONS

- Carbonate
- Bicarbonate
- Chloride
- Sulfate
- Nitrate

ORGANICS

- Oil and Grease
- Hazardous Substances List - Volatiles***
  - Chloromethane
  - Bromomethane
  - Vinyl Chloride
  - Chloroethane
  - Methylene Chloride
  - Acetone
  - Carbon Disulfide
  - 1,1-Dichloroethene
  - 1,1-Dichloroethane

TABLE 2-9 (CONTINUED)

PHASE I AND PHASE II RI
GROUND-WATER AND SURFACE WATER SAMPLING PARAMETERS

ORGANICS

Hazardous Substances List - Volatiles*** (Continued)

- trans-1,2-Dichloroethene
- Chloroform
- 1,2-Dichloroethane
- 2-Butanone
- 1,1,1-Trichloroethane
- Carbon Tetrachloride
- Vinyl Acetate
- Bromodichloromethane
- 1,1,2,2-Tetrachloroethane
- 1,2-Dichloropropane
- trans-1,3-Dichloropropene
- Trichloroethene
- Dibromochloromethane
- 1,1,2-Trichloroethane
- Benzene
- cis-1,3-Dichloropropene
- 2-Chloroethyl Vinyl Ether
- Bromoform
- 2-Hexanone
- 4-Methyl-2-pentanone
- Tetrachloroethene
- Toluene
- Chlorobenzene
- Ethyl Benzene
- Styrene
- Total Xylenes

RADIONUCLIDES

- Gross Alpha
- Gross Beta
- Uranium 233+234, 235, and 238
- Americium 241
- Plutonium 239+240
- Strontium 90
- Cesium 137
- Tritium

* For surface water samples only
** Dissolved metals for ground-water samples, total and dissolved metals for surface water samples
*** Ground-water samples from the first quarter of 1987, and all surface water samples were analyzed for 9 of the HSL volatiles. These volatiles are the chlorinated solvents historically detected in the ground water and are as follows PCE, TCE, 1,1-DCE, 1,2-DCA, t-1,2-DCE, 1,1,1-TCA, 1,1,2-TCA, CCl_4 and $CHCl_3$

TABLE 2-10

VOLATILE ORGANIC COMPOUNDS DETECTED IN
UNCONFINED GROUND WATER
(FOURTH QUARTER 1986 TO FIRST QUARTER 1990)
(MAXIMA)

Material	Well	Chloro-form (µg/l)	Carbon Tetra-chloride (µg/l)	Tetra-chloro-ethene (µg/l)	Tri-chloro-ethene (µg/l)	Methy-lene Chloride (µg/l)	1,1-Di-Chloro-ethene (µg/l)	1,1-Di-Chloro-ethane (µg/l)	1,2-Di-Chloro-ethane (µg/l)	1,1,1-Tri-chloro ethane (µg/l)	1,1,2-Tri-chloro ethane (µg/l)	1,1,2,2-Tetra chloro ethane (µg/l)	Toluene (µg/l)	Ethyl benzene (µg/l)	Acetone
Rocky Flats Alluvium	01-87					3JB				130					3JB
	51-87		1J	8	3J	3JB				3J			9		20B
	52-87		3J	2J	5	21JB				5			1J		190
Colluvium	09-74	5	28000	13200	72000	1300B	48000	180J	16000	30250	14740		81J		9J
	10-74	100J	8100	350	3600	580B	190		140	312			5J		120B
	63-86	dry													
	69-86					1JB									83
	02-87	5J		35J	2J	35B	6						5J		65B
	04-87	6	29	84	525	15B	8		32	20			2JB		56B
	06-87		1J		20	3JB									20B
	43-87		2995	8100	17000	1500B	32687	344	25	28000E	160J		270JB	6	180JB
	44-87	dry													
	47-87	1J	1J			8B									5J
	48-87		3J			2JB									12
	49-87	dry													
	50-87			3J		2JB									4JB
	53-87		6	3J	23	21	21			18			11		9JB
	54-87	8		4J		11B			3J	2J			1J		[illegible]

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TABLE 2-10 (cont.)

VOLATILE ORGANIC COMPOUNDS DETECTED IN
UNCONFINED GROUND WATER
(FOURTH QUARTER 1986 TO FIRST QUARTER 1990)
(MAXIMA)

Material	Well	Carbon disulfide	2-Butanone	Vinyl Acetate	Total 1,2, Dichlorethene	Total Xylenes	Benzene
Rocky Flats Alluvium	01-87		10			2J	
	51-87						
	52-87	5					
Colluvium	09-74		22				
	10-74			39J			
	63-86						
	69-86	1J					
	02-87						
	04-87						
	06-87						
	43-87				5070	2J	83J
	44-87						
	47-87						
	48-87	1J					
	49-87						
	50-87						
	53-87	1J					
	54-87						

TABLE 2-10 (cont.)

VOLATILE ORGANIC COMPOUNDS DETECTED IN
UNCONFINED GROUND WATER
(FOURTH QUARTER 1986 TO FIRST QUARTER 1990)
(MAXIMA)

Material	Well	Chloro-form (µg/l)	Carbon Tetra-chloride (µg/l)	Tetra-chloro-ethene (µg/l)	Tri-chloro-ethene (µg/l)	Methy-lene Chloride (µg/l)	1,1-Di-Chloro-ethene (µg/l)	1,1-Di-Chloro-ethane (µg/l)	1,2-Di-Chloro-ethane (µg/l)	1,1,1-Tri-chloro ethane (µg/l)	1,1,2-Tri-chloro ethane (µg/l)	1,1,2,2-Tetra chloro ethane (µg/l)	Toluene (µg/l)	Ethyl benzene (µg/l)	Acetone
Colluvium (continued)	59-86R					3JB									[illegible]
Valley Fill Alluvium	58-86														
	64-86			8J		3J									2J
	68-86					24									7JB
	55-87					8									19
Weathered Sandstone	62-86		2J	29J		73B									2JB
	05-87	8	170		45	9JB			6						99
	59-86			6											2JB
Unweathered Sandstone	0387			5J	6	68							2J		33B
	4587	37B				23JB							0.7JB		[illegible]
	0887	3J	130	20	35	4J	2J						1J		120

J - Estimated value below Contract Required Detection Limit (CRDL) High concentrations associated with a "J" indicate a dilution of the sample was necessary for analysis, which increased the CRDL.

E - Estimated value beyond standard curve limits

B - Present in Blank

TABLE 2-10 (cont.)

VOLATILE ORGANIC COMPOUNDS DETECTED IN
UNCONFINED GROUND WATER
(FOURTH QUARTER 1986 TO FIRST QUARTER 1990)
(MAXIMA)

Material	Well	Carbon disulfide	2-Butanone	Vinyl Acetate	Total 1,2, Dichlorethene	Total Xylenes	Benzene
Rocky Flats Alluvium	59-86R	1J					
Valley Fill Alluvium	58-86						
	64-86		3JB				
	68-86						
	55-87	1J					
Weathered Sandstone	0387						
	4587	5					
	0887						

At the westerly group of IHSSs, four volatile organic compounds occurred above detection limits in three wells At well 1-87 there was one occurrence of 1,1,1-TCA [130 milligrams per liter (μg/ℓ)], at well 54-87 there was one report each of chloroform ($CHCl_3$, 8 μg/ℓ), PCE (4 μg/ℓ), and 1,1,1-TCA (2J μg/ℓ), and at well 2-87 there was 1,1-DCE (6 μg/ℓ) and PCE (35J μg/ℓ) The only other volatile organic compounds at the westerly IHSSs were methylene chloride (maximum - 35B μg/ℓ at well 2-87), and acetone (maximum - 280 μg/ℓ at well 1-87) Numerous other samples had methylene chloride and acetone concentrations estimated below detection limit and/or present in the blanks for wells that were otherwise free of organics. These results may indicate laboratory rather than site contamination Isolated, low level reports of carbon disulfide, 2-butanone and total xylenes are shown in Table 2-10

At the easterly group of IHSSs (119 1, 119 2, and 130), volatile organic contamination is more pronounced (Table 2-10) Wells 9-74, 10-74, and 43-87 show the most contamination, with PCE, TCE, 1,1-dichloroethene (1,1-DCE), 1,1-dichloroethane (1,1-DCA), 1,1,1-TCA, 1,1,2-trichloroethane (1,1,2-TCA), and carbon tetrachloride (CCl_4) reaching several thousand μg/ℓ in many samples. Chloroform, toluene, 1,2-dichloroethene (1,2-DCA), and total 1,2-dichloroethene occurred at lower concentrations [estimated at less than detection limit or less than 100μg/ℓ with few exceptions (Table 2-10)] Levels of methylene chloride and acetone were typically low enough to be considered laboratory artifact according to CLP protocol (U S EPA, 1988a), although the high levels at wells 9-74, 10-74, and 43-87 suggest the actual presence of these compounds in the ground water at these locations Carbon disulfide, 2-butanone, vinyl acetate total xylene and benzene results in Table 2-10 show sporadic occurrences at low concentrations

The report of low level PCE for well 64-86 (8J μg/ℓ) in the second quarter 1989 was not repeated in subsequent analyses Planned monitoring will help confirm the presence or absence of contamination in downgradient valley fill alluvium

In weathered sandstone, well 5-87 contained organics other than methylene chloride and acetone with PCE (170 μg/ℓ), TCE (45 μg/ℓ), $CHCl_3$ (8 μg/ℓ), and 1,2-DCA (6 μg/ℓ) The acetone was also quite high in that well (99 μg/ℓ) Well 62-86 had 29J μg/ℓ of PCE and 2J μg/ℓ of CCl_4 Only 6 μg/ℓ of PCE was reported for well 59-86

Confined Ground Water

Volatile organics have been infrequently detected in samples of confined ground water of the unweathered sandstones (wells 3-87, 45-87, and 8-87) At least 11 quarters of data exist for these wells. There were no greater than four occurrences of methylene chloride and acetone in samples from each well In almost every case, the concentrations were either estimated below detection limits and/or these analyses were present in the associated laboratory blank There are only two occurrences of 1,1-DCE (1J $\mu g/\ell$ and 2J $\mu g/\ell$), both in samples from well 8-87 Three samples from well 45-87 (fourth quarter 1987 and the first two quarters of 1988) contained chloroform (range 3J $\mu g/\ell$ to 37B $\mu g/\ell$) However, chloroform was not present in any sample from subsequent quarters Toluene was present in only one sample from each of the three wells. Concentrations ranged from 0 7JB $\mu g/\ell$ to 2J $\mu g/\ell$ TCE was detected only once in samples from well 3-87 (6 $\mu g/\ell$) and only twice in samples from well 8-87 (2J $\mu g/\ell$ and 35 $\mu g/\ell$) TCE was not detected in well 45-87 PCE was only detected once in well 3-87 (5J $\mu g/\ell$) and twice in well 8-87 (2J $\mu g/\ell$ and 20 $\mu g/\ell$) PCE was not detected in well 45-87 CCl_4 was only detected once in well 8-87 (130 $\mu g/\ell$), and was not detected in wells 3-87 and 45-87 Carbon disulfide was detected once (5$\mu g/\ell$) in well 45-87 only It is concluded that the ground water in the unweathered sandstone at Operable Unit No 1 is not contaminated for the following reasons

- the common laboratory contaminants, acetone and methylene chloride, are not detectable in samples at least 60 percent of the time, and when detected, concentrations are low and/or the associated laboratory blank contained these contaminants, and
- all of the data, with the exception of the results for samples noted above, showed no volatile organic compounds These data include numerous sampling events, preceding and succeeding the infrequent detections

2 3 3 2 Inorganics

Major Ions in Unconfined Ground Water

All surficial materials wells (except dry wells 51-87, 53-87, and 58-86) in the vicinity of the western group of IHSSs contained some major anions above background The margin above background was small in many cases, and therefore presents only ambiguous evidence of contamination However the occurrences of nitrate significantly above estimated background [maxima of 7 7 milligrams per liter (mg/ℓ) in well 69-86, 55 mg/ℓ

in well 68-86], of chloride and/or sulfate above 100 mg/ℓ in wells 1-87, 52-87, 69-86, and 53-87, and total dissolved solids (TDS) above 1000 mg/ℓ in wells 52-87, and 69-86, do indicate that anions are significantly elevated in these wells. Cyanide was analyzed for wells 52-87, 69-86, and 68-86, and occurred above background in one sample (0 106 mg/ℓ in well 69-86)

Major cations magnesium and sodium are significantly elevated at all of the wells in this group except at wells 68-86 and 54-87 Major cations calcium and potassium are also somewhat elevated at some of these wells

Several surficial wells in the vicinity of IHSSs 119 1, 119 2 and 130 also contained major anions above background (9-74, 10-74, 2-87, 4-87, 6-87, 43-87, 48-87 and 64-86) Wells 9-74 and 10-74 showed the highest concentrations of nitrate (91 2 and 55 mg/ℓ) and these wells had similar concentrations (several hundred mg/ℓ) of other major anions relative to the other wells TDS was typically approximately 2000 mg/ℓ Several of these wells were intermittently dry and therefore the available data cannot provide detailed trends However there is an association between IHSS 119 1 and the highest inorganic constituent results Isopleths of TDS and nitrate (Figures 2-11 and 2-12) for the second quarter of 1989 illustrate this, and are generally consistent with data for other sampling events Major cations calcium, magnesium and sodium were above background in almost all samples in this area

Both of the wells in weathered sandstone which were not persistently dry contained major ions above background TDS was typically just over 2000 mg/ℓ and chloride and sulfate were several hundred mg/ℓ as in the surficial wells, and nitrate was elevated up to ten times background Calcium, magnesium and sodium were slightly above background

Major Ions in Confined Ground Water

The ground water in the deeper wells, in contrast to the unconfined flow system, did not contain a large suite of elevated inorganics in the surficial ground-water system Only well 8-87 with a maximum TDS of 450 mg/ℓ and nitrate at 1 mg/ℓ had anions slightly above background Calcium and magnesium were the only elevated cations in that well

Metals in Unconfined Ground Water

All wells in surficial materials in the vicinity of the western group of IHSSs had some metals above background, but the suite of elevated metals was not consistent spatially or temporally Nickel, strontium, zinc, manganese, mercury and copper each exceeded background in three or more wells, and barium, beryllium, iron, antimony, chromium, lead, aluminum and cadmium occurred slightly above background in one or two wells

Nickel, strontium, selenium, zinc and copper exceeded background in several samples from most wells near the eastern group of IHSSs, and several elements exceeded background once or infrequently (aluminum, antimony, barium, cadmium, chromium, cobalt iron, lead, mercury, molybdenum and potassium)

The concentrations of selenium, strontium, nickel and zinc shown in Figures 2-13 to 2-16 are generally consistent with the patterns of high concentrations of inorganics around IHSS 119 1, although the dry wells and typically low concentrations hinder portrayal of possible patterns in the metals data The data sets for cesium, lithium, molybdenum, and tin are incomplete because the laboratory did not analyze for those elements in many samples Ground water in the weathered bedrock wells contained most of the metals that were elevated in surficial materials as well as lithium in well 5-87 up to 25 times background

Metals in Confined Ground Water

Of the deeper wells in unweathered units, only 8-87 contained metals that were elevated (nickel, strontium, manganese and iron exceeded estimates of background by more than a factor of four) The unweathered sandstone wells exhibited low concentrations for other elements (cadmium, chromium, barium, lithium, iron, mercury, and silver) which were either undetected or extremely low in background samples

Radionuclides in Unconfined Ground Water

Of the wells in surficial materials near the western group of IHSS's, five contained gross-alpha and beta, uranium and tritium above background (wells 1-87, 52-87, 69-86, and 59-86R) Within that group of wells, total uranium was typically less than 30 picoCuries per liter (pCi/ℓ) except at well 52-87 (maximum was 64 2 pCi/ℓ) Gross alpha and beta were highest at that well also (70 pCi/ℓ and 76 pCi/ℓ, respectively) The magnitude and frequency of those results suggest possible radionuclide contamination at this location Analytical results for strontium-89,90, cesium-137, and americium-241 were not reported by the laboratory for many samples. Occurrences of tritium above background in wells 52-87 and 69-87, and americium and radium-226 in well 52-87 are isolated and just above background Therefore a determination of contamination based on those data is inconclusive

Well 4-87 of the eastern group of wells in surficial materials contained the highest concentrations of radionuclides Maximum gross alpha and beta results were approximately 300 pCi/ℓ, total uranium was approximately 50 pCi/ℓ, and tritium reached 777 pCi/ℓ Wells 9-74, 10-74, 6-87, and 43-87 contained these radionuclides above background, although the maximum levels were much lower than at 4-87 Strontium-89,90 also exceeded background at several of these wells (maximum was 5 6 pCi/ℓ at well 2-87), whereas cesium-137 and radium-226 were just above background in one or two samples Gross alpha and beta, uranium and tritium exceeded background in both weathered sandstone wells, whereas strontium-89,90 was elevated only in well 5-87 The concentrations are lower than in surficial materials with the exception of gross alpha and beta (99 and 91 pCi/ℓ in well 5-87)

Figure 2-17 portrays the distribution of total dissolved uranium in the unconfined ground-water flow system for the second quarter of 1989 The principal feature, elevated uranium concentrations in the vicinity of IHSS 119 1, is consistent with the data available from other sampling periods Because well 49-87 is persistently dry, the amount of contamination between wells 4-87 and 6-87 is unknown

Radionuclides in Confined Ground Water

Unweathered sandstone wells had either gross alpha or beta above background, one instance of uranium-235 above background in well 8-87, and one case of radium-226 just above background All other analytes were below background

2 3 3.3 Summary of Extent of Contamination

Organic, and possibly major ion, trace metal and uranium contamination exist in ground water within surficial materials and in some bedrock at the 881 Hillside Area. Volatile organic contamination is most severe in the eastern portion of the site, and may be derived primarily from IHSS 119 1 The available data suggest that organic contamination is restricted to a small area around that apparent source The ground-water data for the western group of IHSS's show frequently unsaturated conditions that may have mitigated contaminant migration The presence of 1,1,1-TCA at well 1-87 may indicate contamination from an upgradient source or from a sidegradient portion of the 881 Hillside Area (IHSS 145) In either case, further characterization is required Uncertainties regarding the origin of methylene chloride and acetone in ground-water samples (site or laboratory contamination) do not alter the fundamental conclusions listed above and can be clarified with additional planned analyses

Conclusions regarding inorganic contamination are limited by the preliminary nature of background data. The preceding sections listed all constituents above background as if each represents contamination On that basis the data indicate distinctly elevated major ions throughout most of the site, and apparent contamination emanating from both the western and eastern portions of the 881 Hillside The extent of such plumes of inorganics at the site has not been delineated by existing data The metals data exceed background more erratically than do the major ions, and offer more ambiguous evidence of contamination emanating from IHSS's It is not currently possible to determine whether this uncertainty is a function of incompletely defined background levels and/or the presence of contaminants from multiple sources The list of elevated constituents includes elements that could be attributed to natural sources in this sedimentary environment (e g selenium, zinc, strontium) as well as elements that may suggest human influence (nickel, beryllium) Radionuclide data are similarly ambiguous However, the uranium concentration in the vicinity of IHSS 119 1 is sufficient impetus for further investigation Interpretation of the extent of elevated uranium must be coordinated with better definition of background conditions Ongoing evaluation of background concentrations and additional data collection at the 881 Hillside will permit more definitive assessment of the influence of Plant operations on ground-water quality

Elevated constituents of all categories have migrated vertically from surficial materials to hydraulically connected upper bedrock units Possible impacts on the bedrock are most significant in the weathered zone

2.3 4 Surface Water

Surface water stations at the 881 Hillside Area are located along the South Interceptor Ditch, Woman Creek, and at various seeps and ponds. Nine surface water stations in the vicinity of the 881 Hillside Area were sampled during field activities. All available surface water data are compared to second quarter 1989 background data to preliminarily assess if inorganic or radionuclide contamination exist at these stations Section 2 3 1 explains the status of these background data. Surface water locations are shown on Figure 2-18, and data are presented in Appendix C

2 3 4 1 South Interceptor Ditch

Surface water stations SW-45, SW-46, and SW-44 are just south of Building 881 SW-45 monitors the foundation drain discharge from Building 881 This water flows into a skimming pond Station SW-44 is the discharge from a pipe draining the skimming pond to the South Interceptor Ditch The foundation drain is a vitrified clay pipe which is buried 14 to 20 feet deep along the western and southern sides of the 881 Building The pipe drains water southward to a common pipe and then into the skimming pond SW-46 is located at a pond formed by ground-water seepage from the 881 Hillside SW-46 is west and hydraulically sidegradient of the skimming pond

Surface water runoff from the 881 Hillside Area flows into the South Interceptor Ditch and then into Pond C-2 Surface water in Woman Creek is routed around Pond C-2, however, water in Pond C-2 is discharged to Woman Creek in accordance with the plant NPDES permit SW-31 monitors water quality in the South Interceptor Ditch just downstream of SW-44 Surface water stations SW-66, SW-67, SW-68, SW-69 and SW-70 monitor the South Interceptor Ditch downgradient from the 881 Hillside

Volatile organics have been detected in samples from SW-45 (Building 881 foundation drain discharge), and at lower concentrations in SW-46 (pond formed by ground-water seepage at 881 Hillside), and SW-44 (discharge to the Interceptor Ditch) The concentration of PCE was 128 $\mu g/\ell$ at SW-45 in May 1987, but was near detection limits and then undetected in subsequent samplings until March 1990 PCE was 23 $\mu g/\ell$ in the last available sample There were isolated instances of toluene (12 $\mu g/\ell$) and CCl_4 (6 $\mu g/\ell$) in late 1987 at this station Samples from SW-46 in May and June 1989 indicate that PCE was present at estimated concentrations below detection limits (3J $\mu g/\ell$ and 2J $\mu g/\ell$, respectively) No other volatile organics were detected in samples from SW-46 SW-44 showed no detectable volatile organic compounds until fourth quarter 1989 (4J $\mu g/\ell$ of TCE), and first quarter 1990 (7 $\mu g/\ell$ of TCE) Methylene chloride and acetone concentrations were low enough to be considered inconclusive evidence of contamination by these organics at SW-44, SW-45, and SW-46

Volatile organics do not appear to be present at surface water stations SW-66, SW-67, SW-68, SW-69 and SW-70 (downgradient South Interceptor Ditch) Methylene chloride, acetone, and 2-butanone were present between 2 and 38 $\mu g/\ell$ at all the stations, however, these compounds were also present in laboratory blanks Toluene was present in a sample from SW-69 only in August 1989 at a level of 4J $\mu g/\ell$ (also present below detection limits) No other volatile organics were detected in South Interceptor Ditch surface water stations downstream from the 881 Hillside Area

Results of inorganic analyses of surface water samples from these stations indicate that TDS, nitrate, and sulfate concentrations fluctuated above and below background Maximum concentrations were generally within a factor of two above background, however, there was one anomalous nitrate result at SW-44 (424 mg/ℓ) At all other stations maximum nitrate concentrations ranged between 4 and 10 mg/ℓ Dissolved magnesium exceeded background by approximately a factor of two at all the stations whereas dissolved calcium and potassium exceeded background by less than 5 mg/ℓ at stations SW 44, SW-45 and SW-46 Both calcium and magnesium consistently exceeded background when analyzed in unfiltered samples, but the margins above background varied Total potassium exceeded background at most of the stations by less than a factor of two

The following dissolved metals occurred intermittently above background aluminum, beryllium, cadmium, copper, mercury, lead, strontium, zinc, chromium, selenium, and vanadium The list of total metals which exceeded background is the same, except that barium and nickel are also included and copper is excluded Strontium and zinc were the only dissolved trace elements above background at nearly every station, however, total aluminum, barium, iron, strontium, and zinc exceeded the background for metals in suspension at most of the stations. Total aluminum tended to exceed background by widely varying margins, reflecting the variable suspended clay content of surface water under different flow conditions Most of the trace metals exceeded background by less than a factor of two, but exceptions are notable For example, mercury was 0 46 mg/e and 0 9 mg/ℓ at stations SW-44 and SW-45 in June 1988

Dissolved gross alpha and beta, uranium and plutonium exceeded background in many of the samples Dissolved radium-226 exceeded background as well, but in only three samples with a relatively low value and high counting error Total radionuclide results exhibit the same constituents above background, as well as strontium-89, 90, americium, cesium-137, and tritium Although the total radiochemistry results are typically higher than dissolved results as expected, the maximum dissolved plutonium did exceed total plutonium at stations SW-45, SW-66, SW-68, SW-69, and SW-70 Because samples for dissolved and total plutonium are separate grab samples it is possible that the data reflect the variable colloidal content of different grab samples

2 3 4 2 Woman Creek

Surface water stations SW-32, SW-33, and SW-34 are located on Woman Creek directly south of the 881 Hillside and South Interceptor Ditch and upstream from the 903 Pad Area Volatile organics were not detected in Woman Creek surface water with exception of presumed laboratory contaminants methylene chloride, acetone, and one instance of toluene at SW 32 (12 μg/ℓ) Results of inorganics analyses from these surface water stations were all within tolerance interval values calculated from Round 1 background surface water sampling results Of the dissolved metals, only zinc at SW-32 to SW-34 (maximum 0 072 mg/ℓ), and strontium at SW-32 (0 496 mg/ℓ) were elevated above background Several major and minor elements exceeded background as at the other surface water stations Radiochemistry data for these stations are analogous to those from the South Interceptor Ditch, although total uranium values are typically lower in Woman Creek Plutonium and americium were both just detectable at several of these stations Radium-226 was not analyzed in the Woman Creek samples

2 3 5 Sediments

Bedload sediment samples were collected during 1989 site characterization from creeks and ditches that traverse the Rocky Flats Plant Sediment stations have been established along the Woman Creek drainage downgradient of the 881 Hillside Area All available data for eleven sampling stations are presented in Appendix D Stations SED-28, SED-29, SED-25 are located (in that order) within the South Interceptor Ditch in the Woman Creek drainage, 750 to 3000 feet downstream from surface water station SW-70 These stations are just east of the 881 Hillside Area shown in Figure 2-17 SED-31 and SED-30 are seeps on the South Interceptor Ditch berm up- and downstream from station SED-29 SED-27 and SED-26 are along Woman Creek just upstream of Pond C-2 All of these stations are hydraulically downgradient of the 903 Pad Area and therefore may be influenced by that source Data for three, more distant stations are included in Appendix D SED-14 and SED-15 are upstream of the 881 Hillside Area (approximately 3300 and 10,000 feet upstream from SW-36), and SED-01 is downstream of the 881 Hillside and 903 Pad Areas (approximately 9000 feet downstream) The sediment station locations described above do not explicitly address sediments that are at the base of the hillside and upgradient of the 903 Pad Therefore the sediment chemistry results described below will be supplemented with data from new sampling stations in subsequent work to the extent possible (Section 5)

Volatile organic compounds were typically undetected or estimated below detection limits with the following exceptions SED-29 and SED-30 contained 60 $\mu g/\ell/kg$ and 19J $\mu g/\ell/kg$ of chloromethane, respectively SED-01, SED-14, SED-29 and SED-30 contained acetone in one sample at each station (85 $\mu g/kg$, 89 $\mu g/kg$, 18 $\mu g/kg$ and 220 $\mu g/kg$, respectively) Acetone was present in the blank at the latter station, so the report of 220 $\mu g/kg$ is of questionable significance Methylene chloride concentrations were 20 $\mu g/kg$ and 22 $\mu g/kg$ at SED-01 and SED-27, again associated with contaminated blanks Chloroform was detected at 18 $\mu g/kg$ in the one sample from SED-31 and the TCE at the same station was 8 $\mu g/kg$

Low-level results, all estimated below detection limit, were reported for carbon disulfide at SED-30 (6J $\mu g/kg$), 2-butanone at SED-01 (1JB $\mu g/kg$), TCE at SED-25, SED-26 and SED30 (5J $\mu g/kg$, 3J $\mu g/kg$, and 7J $\mu g/kg$), toluene at SED-29 and SED-30 (2J $\mu g/kg$ and 6J $\mu g/kg$), and methylene chloride and/or acetone at most stations The presence of acetone at upgradient SED-01, together with the low concentrations and contaminated blanks, demonstrate that the evidence of volatile organic compounds in these sediments is insufficient to prove contamination

Nitrate exceeded background at SED-01, SED-25, SED-26, SED-29, SED-30, and SED-31 The maximum concentration was 8 1 mg/kg at SED-30 Magnesium and potassium were the two major cations above background (5970 mg/kg and 67000 mg/kg, respectively)

Concentrations of beryllium, silver, and tin were the most elevated in the sediment of the South Interceptor Ditch Concentrations of silver were more than five times the upper limit of the background range at SED-25, SED-29 and SED-30 (maximum was 49 1 mg/kg) Beryllium undetected in background samples, and 2 5 mg/kg in upgradient station SED-15, ranged from 3 8 to 15 5 mg/kg in the South Interceptor Ditch sediments Tin was above background at stations SED-25, SED-26, SED-29 and SED-30, ranging from 364 to 1080 mg/kg

Several other metals exceeded background by smaller margins in one or two samples each from the downgradient stations SED-25 to SED-31, including aluminum, antimony, cadmium, chromium, copper, iron, lead, lithium, magnesium, manganese, mercury, selenium, strontium, thallium, vanadium, and zinc Woman Creek sediment samples, in contrast, contained only mercury and molybdenum above background (0 48 µg/kg of mercury at SED-14, and 40 mg/kg and 42 mg/kg at SED-14 and SED-15, respectively)

Plutonium was the principle radionuclide above background, occurring at concentrations ranging from 0 08 pCi/g to 3 3 pCi/g at stations SED-25, SED-26, SED-29, SED-30 and SED-31 The presence of plutonium in the sediments is consistent with the soil plutonium contamination found in the 881 Hillside and 903 Pad Areas Other exceedances of background (4 8 pCi/g of total uranium at SED-25, and 77 pCi/g of gross-alpha and 1 3 pCi/g of radium-226 at SED-30) occurred in single samples The Woman Creek sediment samples did not contain plutonium or other radionuclides above background

2 3 6 Air

Air quality studies at the Plant are performed continuously and reported annually in the Annual Environmental Monitoring Reports (e g , Rockwell International, 1975 through 1985, 1986b, and 1987b) In addition, the air pathway was further characterized in Rockwell International (1986f)

Air samplers for routine ambient air monitoring at the Plant are located at various locations on and off the Plant site The ambient air program monitors radionuclide concentrations, conventional air quality parameters are also monitored on site at a dedicated location inside the perimeter security fence, west of the East Guard Gate

The Plant Radioactive Ambient Air Monitoring Program (RAAMP) consists of 51 high-volume particulate air samplers which operate continuously Twenty-three of the 51 samplers are within or directly adjacent to the Plant security area (on-site samplers) and 14 are located around the property boundary (perimeter samplers) An additional 14 samplers are located in neighboring towns (community samplers)

The 903 Pad Area is recognized as the principal source of airborne plutonium contamination at the Plant (Rockwell International, 1975 through 1985, 1986b, and 1987b) Historically, the particulate samplers located immediately east, southeast, and northeast of the 903 Pad, Mound, and East Trenches Areas have shown the highest plutonium concentrations This finding is corroborated by the results of soil surveys which indicate elevated plutonium concentrations to the east, particularly the southeast of the area However, the RAAMP has found ambient air samples to be well within applicable regulations and guidelines for the protection of human health and the environment for all radioactive contaminants (Rockwell International, 1987a)

2 3 7 Biota

The biota at the 881 Hillside Area have not specifically been previously studied, however studies on the biota at the 903 Pad, Mound and East Trenches Area have been conducted A survey was conducted for the Final Environmental Impact Statement, Rocky Flats Plant Site (U S DOE, 1980), and previous studies were summarized in the Radioecology and Airborne Pathway Data Summary Report (Rockwell International, 1986f) The Radioecology and Airborne Pathway Data Summary Report addresses the plutonium released from the

903 Drum Storage Site and its effects on the immediate environment Field studies were conducted over several years which compared various biological measurements and pathological data between ecologically similar study areas of widely varying plutonium levels Soil plutonium concentrations were measured along with biological measurements such as vegetation community structure and biomass, litter mass, arthropod community structure and biomass, small mammal species occurrence, population density, biomass, reproduction, and physical size of whole carcasses and organs In addition, pathological examination of small mammals, including x-ray for skeletal sarcomas, microscopy for lung tumors, and necropsy for general pathology and parasite occurrence were carried out. Results of the studies showed no evidence of ecological impacts attributable to plutonium Although pathological conditions were found in some rodents, there were no significant pathological differences between control and plutonium contaminated areas. Other minor differences in biological attributes for study are as at the Plant site could not be correlated to plutonium levels

Aquatic studies, conducted by Colorado State University, examined phytoplankton, some detritus and small zooplankton uptake of plutonium from the B-series holding ponds This study showed than an "increase in trophic-level concentration of plutonium did not occur apparently due to a selective mechanism that discriminated against plutonium at this level This would result in a decreased potential hazard when considering the transfer of plutonium through ingestion routes" (Paine, 1980)

Other aquatic studies revealed that 77% of the plutonium associated with crayfish is found in their exoskeleton Fish flesh and bone from the A and C-series ponds were never above the minimum detectable activity for plutonium

2 4 APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

Section 121(d) of CERCLA, as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA), requires that Fund-financed, enforcement, and Federal facility remedial actions comply with applicable or relevant and appropriate (ARAR) Federal laws, or more stringent promulgated State laws

Health-based, chemical-specific ARARs pertinent to ground-water quality have been identified for the EPA CLP TCL organic and TAL inorganic compounds as well as radionuclides and conventional pollutants found above detectable levels The chemical-specific ARARs are derived primarily from federal and state health and environmental statutes and regulations As discussed below, in some instances these standards are classified as items to be considered (TBCs) A summary of chemical-specific ARARs for the contaminants found at the 881 Hillside Area is presented in Table 2-11

The ARARs listed in Table 2-11 were identified by examining the following promulgated standards

- Safe Drinking Water Act (SDWA) Maximum Contaminant Levels (MCLs) and Maximum Contaminant Level Goals (MCLGs),
- Clean Water Act (CWA)
- Ambient Water Quality Criteria (AWQC),
- RCRA Subpart F concentration limits (40 CFR 264 94),
- CDH surface water standards for Woman Creek (5 CCR 1002-8, Section 3 8 29, Final Rule Effective March 30, 1990), and
- CDH ground-water standards (5 CCR 1002-8, Section 3 11 5)

The NCP [FR Vol 55, No 46, 8848, 40 CFR 300 430 (e)] requires that, in development of alternatives for final remediation, the following be considered for current or potential sources of drinking water attainment of MCLGs or MCLs, if MCLGs are zero, and attainment of CWA AWQC where relevant and appropriate Because surface water at OU1 is a source of drinking water, the MCLGs (or MCLs) are relevant and appropriate The AWQC are also relevant and appropriate because Woman Creek has a use-protected designation, aquatic life class II warm water The RCRA Subpart F concentration limits include standards for 14 compounds, with background or alternate concentration limits used as the standard for the other 40 CFR 261, Appendix VIII constituents Although this area does not contain RCRA-regulated units for which these standards are applicable, it does contain IHSSs Therefore, these RCRA Subpart F regulations are considered relevant and appropriate However, because ACLs based on protection of public health have not been established for the Appendix VIII constituents, the RCRA clean-up criteria of background concentration are viewed as TBC Background concentrations for 40 CFR 264, Appendix IX constituents not listed in Appendix VIII are also TBC The CDH surface water quality standards for Segment 4 of Woman Creek (downstream of Pond C-2) are designated as goals for Segment 5 Pond C-2 and upstream (includes Operable Unit No 1) Although the CDH surface water quality standards for Woman Creek are only goals in the reach adjacent to Operable Unit No 1, they are considered relevant and appropriate because the lower reaches must attain these standards, and therefore cannot be impacted by releases from the 881 Hillside Area The CDH ground-water standards are

TABLE 2-11
CHEMICAL SPECIFIC ARARs
FOR COMPOUNDS AND ELEMENTS DETECTED
AT THE 881 HILLSIDE AREA

Chemical	Maximum In 881 Hillside Area Alluvial Ground Water[a] (mg/ℓ)	ARAR (mg/ℓ)	Detection Limit/ GC PQL (mg/ℓ)	ARAR Reference	Comment
Organic Compounds					
Acetone	280	50	10	RCRA Land Disposal Restriction (LDR)	
Carbon Tetrachloride	28,000	5	5	CDH Surface Water Drinking Water Standard	
1,1-Dichloroethane	342	5U	5	RCRA Subpart F	Detection limit is TBC
1,2 Dichloroethane	16,000	5	5	CDH Surface Water Drinking Water Standard	
1,1-Dichloroethene	48,000	7	5	CDH Surface Water Drinking Water Standard	
Methylene Chloride	1,500B	5U	5	RCRA Subpart F	Detection limit is TBC
Tetrachloroethene	13,200	0 8	1*	CDH Surface Water, Fish and Water Ingestion Standard	The detection limit [CDH Practical Quantitation Limit (PQL)] of 1U for GC is ARAR
Toluene	270JB	2000	5	SDWA MCLG	Maximum detected concentration is below ARAR
1,1,1-Trichloroethane	30,250	200	5	CDH Surface Water Drinking Water Standard	
1,1,2-Trichloroethane	14,740	0 6	1*	CDH Surface Water, Fish and Water Ingestion Standard	The detection limit (CDH PQL) of 1U for GC is ARAR
Trichloroethene	72,000	5	5	CDH Surface Water Drinking Water Standard	

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TABLE 2-11 (cont.)
CHEMICAL SPECIFIC ARARs
FOR COMPOUNDS AND ELEMENTS DETECTED
AT THE 881 HILLSIDE AREA

Chemical	Maximum In 881 Hillside Area Alluvial Ground Water[a] (mg/ℓ)	ARAR (mg/ℓ)	Detection Limit/ GC PQL (mg/ℓ)	ARAR Reference	Comment
Organic Compounds (cont)					
Carbon Disulfide	8	5U	5	RCRA Subpart F	Detection limit is TBC
1,1,2,2-Tetrachloroethane	5U	0 17	1*	CDH Surface Water, Fish and Water Ingestion Standard	Detection limit (CDH PQL) of 1U for GC is ARAR.
Ethyl Benzene	6	680	5	CDH Surface Water Standard	Maximum detected concentration is below ARAR
Chloroform	73	0 19	1*	CDH Surface Water, Fish and Water Ingestion Standard	Detection limit (CDH PQL) of 1U for GC is ARAR

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TABLE 2-11 (cont.)
CHEMICAL SPECIFIC ARARs
FOR COMPOUNDS AND ELEMENTS DETECTED
AT THE 881 HILLSIDE AREA

Chemical	Maximum In 881 Hillside Area Alluvial Ground Water[a] (mg/ℓ)	ARAR (mg/ℓ)	Detection Limit/ GC PQL (mg/ℓ)	ARAR Reference	Comment
Dissolved Metals					
Aluminum	4 75	5 0	0 20	CDH Agriculture Standard	Maximum detected concentration is below ARAR.
Antimony	0 208	0 06U	0 06	RCRA Subpart F	Detection limit (Background) is TBC
Arsenic	009	0 05	0 01	CDH Surface Water Drinking Water Standard	Maximum detected concentration is below ARAR
Barium	0 926	1 0	0 20	CDH Surface Water Drinking Water Standard	Maximum detected concentration is below ARAR
Beryllium	0 029	0 1	0 005	CDH Ground Water Agricultural Standard	Maximum detected concentration is below ARAR
Cadmium	007	0 01	0 005	CDH Surface Water Drinking Water Standard	Maximum detected concentration is below ARAR.
Calcium	356 00	NS	5	No Standard	
Cesium	0 04J	NS	1 0	No Standard	
Chromium III	0 0782	05	0 01	CDH Surface Water Drinking Water Standard	Analytical result is total chromium.
Chromium VI	0 0782	05	0 01	CDH Surface Water, Drinking Water Standard	Analytical result is total chromium
Copper	3 13	0.2	0 025	CDH Ground Water Agriculture Standard	
Iron	5 82	0 3	0 1	CDH Surface Water Drinking Water Standard	Analytical results are soluble iron
Lead	0 037	0 05	0 005	CDH Surface Water Drinking Water Standard	Maximum detected concentration is below ARAR.

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TABLE 2-11 (cont)
CHEMICAL SPECIFIC ARARs
FOR COMPOUNDS AND ELEMENTS DETECTED
AT THE 881 HILLSIDE AREA

Chemical	Maximum In 881 Hillside Area Alluvial Ground Water[a] (mg/ℓ)	ARAR (mg/ℓ)	Detection Limit/ GC PQL (mg/ℓ)	ARAR Reference	Comment
Dissolved Metals (cont)					
Lithium	0 7	2 5	0 1	CDH Ground Water Standard	Maximum detected concentration is below ARAR
Magnesium	105	NS	5	No Standard	
Manganese	3 33	0 05	0 015	CDH Surface Water Drinking Water Standard	Analytical results are soluble manganese.
Mercury	0 006	0 002	0 0002	CDH Surface Water Drinking Water Standard	
Molybdenum	0 185	0 1	008	CDH Ground Water Agriculture Standard	
Nickel	11 70	0 2	0 04	CDH Ground Water Agriculture Standard	
Potassium	54 8	NS	5	No Standard	
Selenium	3 2	0 01	0 005	CDH Surface Water Drinking Water Standard	
Silver	0 031	0 05	0 01	CDH Surface Water Drinking Water Standard	Maximum detected concentration is below ARAR
Sodium	341 75	NS	5	No Standard	
Strontium	3 06	NS	0 2	No Standard	
Thallium	0 016	0 01U	0 01	RCRA Subpart F	Detection limit (Background) is TBC.
Vanadium	0 0368	0 1	0 05	CDH Ground Water Agriculture Standard	Maximum detected concentration is below ARAR
Zinc	2 4559	2 0	0 02	CDH Ground Water Agriculture Standard	

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TABLE 2-11 (cont.)
CHEMICAL SPECIFIC ARARs
FOR COMPOUNDS AND ELEMENTS DETECTED
AT THE 881 HILLSIDE AREA

Chemical	Maximum In 881 Hillside Area Alluvial Ground Water[a] (mg/ℓ)	ARAR (mg/ℓ)	Detection Limit/ GC PQL (mg/ℓ)	ARAR Reference	Comment
Conventional Pollutants					
pH	7 0-9 9	6 5-9 0	0 1	CDH Ground Water Standard	
Nitrite	91 2	1 0	1 0	CDH Ground Water Standard	Analytical results are total nitrite plus nitrate as nitrogen. Reanalysis required to determine if nitrite ARAR is exceeded
Nitrate	91 2	10 0	5	CDH Ground Water Standard	Analytical results are total nitrite plus nitrate as nitrogen Results indicate that nitrate ARAR is exceeded
Chloride	838	250	5	CDH Ground Water Standard	
Sulfate	1110	250	5	CDH Ground Water Standard	
Bicarbonate as $CaCO_3$	640	NS	10	No Standard	
TDS	2374	400	5	CDH Ground Water Standard	
Cyanide	0 1060	005	005	CDH Surface Water Standard	Analytical results are total cyanide

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TABLE 2-11 (cont)
CHEMICAL SPECIFIC ARARs
FOR COMPOUNDS AND ELEMENTS DETECTED
AT THE 881 HILLSIDE AREA

Chemical	Maximum In 881 Hillside Area Alluvial Ground Water[b]	ARAR (pCi/ℓ)	Detection Limit (pCi/ℓ)	ARAR Reference	Comment
Radionuclides					
Gross Alpha	319±241	7	2	CDH Surface Water Standard	
Gross Beta	286±83	5	4	CDH Surface Water Standard	
$Pu^{238\ 239\ 240}$	0 211±0 074	0 05	0 01	CDH Surface Water Standard	
Am^{241}	<0 01[c]	0 05	0 01	CDH Surface Water Standard	Maximum detected concentration is below ARAR
H^3	777	500	400	CDH Surface Water Standard	
$Sr^{89\ 90}$	5 6	8	1	CDH Surface Water Standard	Maximum detected concentration is below ARAR
$Uranium^{total}$	64.2	5	1 8	CDH Surface Water Standard	

(a) - Maximum compound concentrations determined from data collected through the first quarter of 1990
(b) - Maximum compound concentrations determined from data collected through the third quarter of 1990
(c) - Below Minimum Detectable Activity (MDA)
U - Detection limit
J - Estimated below detection limit
B - Compound also present in blank
* - Detection limit exceeds ARAR

considered applicable When more than one potential chemical-specific ARAR was identified for a contaminant the most stringent standard was used to determine the specific ARAR to be applied

Of the elements/compounds detected in alluvial ground water at the 881 Hillside Area, there are no ARARs for calcium, magnesium, potassium, sodium, bicarbonate, cesium, and strontium However, the TDS ARAR establishes the acceptable aggregate concentration for the above major ions (excludes cesium and strontium) Until an acceptable risk based concentration is established for cesium and strontium, their background concentration is TBC

Table 2-11 shows that several of the volatile organics, metals, and major ions that were analyzed have exceeded potential chemical-specific ARARs from late 1986 to first quarter 1990 at some locations in the 881 Hillside Area This is not to say that releases of these constituents are occurring, for the concentrations of some substances may be due to a past release or to natural geochemical processes However, the listing of Table 2-11 has been presented to identify parameters for which analyses should be made in Phase III and their respective minimum acceptable detection limits The draft final FS will evaluate technologies that address these constituents

2 5 SAMPLING AND ANALYSIS REQUIREMENTS FOR REMEDIAL ALTERNATIVES EVALUATION

The purpose of this section is to identify potential remedial technologies which are consistent with the available information regarding contamination at the 881 Hillside Area Based on the available site information, the contaminated media or areas for which remedial alternatives will be developed include wastes, soil/sediment, ground water, and surface water The following general remedial response actions were identified for further review and evaluation in the draft FS (Rockwell International, 1988b)

- Complete or partial removal of wastes and contaminated soils,
- In-situ contaminated soils treatment,
- Ground-water collection,
- Infiltration and ground-water containment controls,
- In-situ ground-water treatment/immobilization, and
- Ground-water/surface water treatment

Combinations of these general response actions are appropriate and were evaluated during the draft FS Table 2-12 presents these general response actions along with applicable component technologies

At the time the draft FS was prepared, the extent and nature of contamination at the 881 Hillside Area was not well defined For example, organic contamination of soils may have been underestimated because maximum concentrations occurred in samples not necessarily collected from "hot spots", and the volatile organic data have since been rejected in the validation process The draft FS did not evaluate treatment and/or disposal of organic contaminated soil, however, the Phase III RFI/RI may indicate such an evaluation is in order With respect to inorganic contaminants, the draft FS did not evaluate treatment technologies for their removal Although this was performed for the 881 Hillside interim action (U S DOE, 1990a), the performance of the interim action treatment system will be important input in reevaluating these technologies for the draft final FS Lastly, inorganic contaminated ground water appears downstream of the interim action collection system designed on the basis of the extent of volatile organic compound contaminated ground water Remedial alternatives that address this issue will be evaluated in the revised FS As shown in Table 2-13, there are specific data requirements that are necessary to evaluate the technologies identified in Table 2-12 These data will provide for a thorough comparative evaluation of all appropriate technologies with respect to implementability, effectiveness, and cost, and allow for informed selection of preferred technologies The Field Sampling Plan (Section 5) reflects these information requirements

TABLE 2-12

RESPONSE ACTIONS AND REMEDIAL TECHNOLOGIES

GENERAL RESPONSE ACTIONS	ASSOCIATED REMEDIAL TECHNOLOGIES
Complete or Partial Removal of Contaminated Soils	• Off-Site Landfill • On-Site Treatment*/Backfill
In-Situ Contaminated Soils Treatment	• Immobilization (cementation and vitrification) • Soil Flushing • Vapor Extraction • Bioreclamation
Ground-Water Collection	• Well Array • Subsurface Drains
Infiltration and Ground-Water Containment Controls	• Capping • Subsurface Barriers
In-Situ Ground-Water Treatment/ Immobilization	• Immobilization • Aeration • Bioreclamation
Ground-Water/Surface Water Treatment	• Bioreclamation Treatment • UV/Peroxide or UV/Ozone • Air Stripping • Carbon Adsorption • Ion Exchange • Electrodialysis • Reverse Osmosis • Coagulation/Filtration

*Thermal Treatment, Solvent Extraction, Immobilization (Cementation and Vitrification), Attrition Scrubbing for Radionuclide Decontamination

TABLE 2-13

REMEDIAL TECHNOLOGY DATA REQUIREMENTS

TECHNOLOGY	DATA PURPOSE	DATA NEEDED*
Off-Site Disposal	Evaluate whether material is acceptable for off site disposal	- 40 CFR 268 Table CCWE and Appendix III Analyses - Full Suite of Radionuclide Analyses
	Cost Analysis	- Vertical and Horizontal Extent* of Contamination
On-Site Treatment/Backfill		
Thermal Treatment	Effectiveness	- Full Suite of Organic and Inorganic Analyses**
	Cost Effectiveness	- BTU Content - Ultimate Analysis**
Solvent Extraction	Effectiveness	- Soil Type (adsorption characteristics) - Soil Organic Matter Content (adsorption characteristics)
Non In Situ (soils) Immobilization/ Cementation	Determine Viscosity of Grout Material	- Soil Grain Size Distribution (sieve analysis)
Non In Situ (soils) Immobilization/ Vitrification	Effectiveness	- Depth of Contamination - Depth of Water Table - Soil Permeability - Metal Content
Attrition Scrubbing	Effectiveness	- Radionuclide Distribution vs Soil Grain Size
In Situ Immobilization/Cementation (soils)	Determine Viscosity of Grout Material	- Soil Grain Size Distribution (sieve analysis)
In Situ Immobilization/Vitrification (soils)	Effectivness	- Depth of Contamination - Depth of Water Table - Soil Permeability - Metal Content
Soil Flushing/Bioreclamation	Effectiveness	- Soil Organic Matter Content - Soil Classification - Soil Permeability - BOD
Vapor Extraction	Effectiveness	- Subsurface Geological Characteristics - Depth to Ground Water - Soil Permeability
Well Array/Subsurface Drain	Hydraulic conductivity Storativity (transient flow)	- Aquifer tests - Hydrogeologic characteristics

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TABLE 2-13 (cont.)

REMEDIAL TECHNOLOGY DATA REQUIREMENTS

TECHNOLOGY	DATA PURPOSE	DATA NEEDED*
Capping/Subsurface Barriers	Suitability of On Site Soils for Use	- Gradation (Sieve Analysis) - Atterberg Limits (Plasticity Tests)
	Effectiveness	- Location of Subcropping Sandstones - Hydraulic Conductivity of Bedrock Materials
	Construction Feasibility	- Grade - Depth to Bedrock - % Moisture - Compaction (Proctor) - Permeability (Triaxial Permeability) - Strength (Triaxial or Direct Shear)
Immobilization (Ground Water Contaminants)	Determine Viscosity of Grout Material	- Soil Grain Size Distribution (sieve analysis)
In-Situ Aeration (Ground Water)	Effectiveness	- Subsurface Geological Characteristics - Depth to Ground Water - Soil Permeability
In-Situ Bioreclamation (Ground Water)	Effectiveness	- Soil Organic Matter Content - Soil Classification - Soil Permeability - BOD - Dissolved Oxygen - NO_3, PO_4^{3-}, pH - Microbial Populations
Above Ground Biological Treatment	Effectiveness	- Soil Organic Matter Content - Soil Classification - Soil Permeability - BOD - Full Suite of Organic Analyses
UV Peroxide Oxidation	Process Control	- Iron and Manganese
Air Stripping	Process Control	- Hardness
	Effectiveness	

* The nature and extent of contamination determined through soils and water analyses for the parameters listed in Tables 2-5 and 2-9 is critical to determining the technical feasibility and cost effectiveness of the technologies listed here

** Ultimate analysis is the determination of percent carbon, hydrogen, sulfur, nitrogen, ash, and oxygen by difference for a dried sample

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SECTION 3

PHASE III RFI/RI WORK PLAN DATA QUALITY OBJECTIVES

The primary objective of a RI is to collect the data necessary to determine the nature, distribution, and migration pathways of contaminants The RI also supports the evaluation of remedial alternatives (U S EPA, 1987) The five general goals of an RI are

1) characterize site physical features,
2) define contaminant sources,
3) determine the nature and extent of contamination,
4) describe contaminant fate and transport, and
5) provide a baseline risk assessment (U S EPA, 1988b)

Data quality objectives (DQOs) are qualitative and quantitative statements which specify the quality and quantity of data collection required by the RI (U S EPA, 1987a) Through application of the DQO process, site-specific RI/FS goals are established, and data needs are identified for achieving those goals This section of the RFI/RI Work Plan reviews conclusions from the Phase I and II RFI/RI as a basis for Phase III RFI/RI objectives and identifies data needs to meet the outlined objectives

3 1 PHASE I AND II RI CONCLUSIONS

Several investigations have been conducted in the vicinity of the 881 Hillside Area to date as discussed in Sections 1 0 and 2 0 General conclusions from these investigations are as follows

1) Surficial materials in the area consist of Rocky Flats Alluvium, colluvium, and valley fill alluvium
2) Bedrock beneath surficial materials consists of Arapahoe Formation claystones and sandstones dipping slightly to the east (less than two degrees) Bedrock materials are weathered below the base of surficial materials
3) Unconfined ground-water flow occurs in surficial materials, subcropping sandstones, and potentially in weathered subcropping claystones The flow system in surficial materials is not fully saturated year round Flow in weathered claystones has not been sufficiently documented, and flow directions in subcropping sandstones are poorly defined due to the complex stratigraphy
4) Confined ground-water flow occurs in deeper sandstones This flow system is poorly defined at this time due to the complex stratigraphy and facies changes

5) Ground-water recharge occurs as infiltration of incident precipitation and flow from ditches and surface water drainages

6) Discharge from the unconfined ground-water flow system occurs as evapotranspiration, seeps and springs at the edge of the Rocky Flats pediment, to surface water in Woman Creek and South Interceptor Ditch, and to bedrock sandstones and claystones

7) Wastes have been buried at IHSS 102 (Oil Sludge Pit Site) and IHSS 103 (Chemical Burial Site) In addition, wastes were potentially dumped or discharged at the Liquid Dumping Site (IHSS 105) and Outfall Site (IHSS 106) Organic contaminants have been released from the Hillside Oil Leak Site (IHSS 107), and the Multiple Solvent Spill Site IHSS 119 1 Soil contaminated with low levels of plutonium has been disposed of at IHSS 130, however, the Phase I and II RI did not detect radionuclide contamination Releases from IHSS 106 (Outfall Site) and IHSS 105 (Out-of-Service Fuel Oil Tanks) have not been determined based on the Phase I and II RI

8) Boreholes were drilled within and adjacent to IHSSs in the Phase I and II RIs, and soil samples were collected and analyzed for Hazardous Substance List (HSL) organics and metals, radionuclides, and inorganics Volatile chlorinated hydrocarbon contamination is apparently limited to soils in the vicinity of boreholes BH01-87, BH57-87, and BH58-87 However, available data were not validated, and further characterization of soils beneath IHSSs is needed

9) Surficial soils in the area are contaminated with plutonium and americium, possibly due to wind dispersal of these radionuclides from the 903 Pad Area Based on soil sampling results, these compounds appear to be limited to the surface, although further definition of source area(s) and extent of contamination is needed

10) Results of RI surface water and ground-water sampling at the 881 Hillside Area indicate that major ions, trace metals, and radionuclides are present above background Volatile organics are also present in ground water downgradient of the 881 Hillside Therefore, further characterization of contaminant sources and pathways is warranted

11) Ground water in surficial materials contains volatile organic compounds The principal volatile organics present are PCE and TCE, but several other compounds are present as well The extent of these contaminants in alluvial ground water has not been fully determined

12) Trace metals including strontium, selenium, nickel, zinc, and others are elevated in the unconfined ground-water flow system Uranium is the principal elevated radionuclide in that system The source and extent of these contaminants has not been defined

13) Elevated uranium has been detected in the South Interceptor Ditch surface water The source of the uranium has not been determined

14) Although the remedial investigations have not provided biological data which specifically address conditions at the 881 Hillside Area, previous studies in that vicinity (903 Pad Area and Plant-wide), indicate non-detectable impacts to biota Considering the locally high concentrations of contaminants and proximity of the 881 Hillside to water and feed for wildlife, further characterization of Operable Unit No 1 is needed

3 2 SITE-SPECIFIC PHASE III RFI/RI OBJECTIVES AND ACTIVITIES

Based on the Phase I and II RI conclusions and the conceptual site model presented in Section 2 0, the site-specific Phase III RFI/RI objectives and associated data needs have been developed (Table 3-1) Specific plans for obtaining the needed data are presented in Section 5 0 (Field Sampling Plan)

High quality data will be collected by following the Rocky Flats Plant ER Program Standard Operating Procedures (SOP) (EG&G, 1990c) and through adherence to the Rocky Flats Plant ER Program Quality Assurance Project Plan (QAPjP) (EG&G, 1990d) and the General Radiochemistry and Routine Analytical Services Protocol (GRRASP) (EG&G, 1990e) Organic and metal analyses will be performed using CLP routine analytical services (RAS), and other analyses (radionuclides and inorganics) will be performed in accordance with the GRRASP-specified methods In addition, analytical methods with detection limits below or near chemical-specific ARARs (see Table 2-11) will be used to facilitate comparison of resulting data to ARARs

TABLE 3-1
PHASE III RFI/RI OBJECTIVES AND ACTIVITIES

Objective	Activity
Characterize Site Physical Features	
1) Determine the extent of saturation and ground-water flow directions for the unconfined flow system both spatially and temporally	- Install additional monitoring wells and piezometers - Maintain a database of water levels from which potentiometric surface maps, saturated thickness maps, cross sections, and hydrographs can be prepared
2) Describe the interaction between the surface water and ground-water pathways	- Compare water levels and water quality data from surface water sampling locations and ground-water monitoring wells to evaluate the interconnection between these two media Data analysis will also rely on ground-water flow directions and seep locations
3) Quantify material properties	- Perform aquifer tests to develop hydraulic conductivity and storage coefficient values for surficial materials
Characterize Contaminant Sources	
1) Characterize the nature and distribution of waste materials remaining on-site	- Collect samples from boreholes drilled directly through IHSSs where possible Collect waste samples as well as soil samples from beneath the wastes Analyze samples for TCL volatiles, semi-volatiles, and pesticides/PCBs, TAL metals, as well as radionuclides and inorganics
2) Characterize soils beneath wastes as well as soils at sites where wastes have been removed as potential contaminant sources	- Same as above
3) Identify which sites or subareas of sites are sources of contaminants in ground water	- Install alluvial ground-water monitoring wells directly beneath sites to assess ground-water levels and quality - Install alluvial ground-water monitoring wells directly up- and downgradient of each site to pinpoint the source of contaminants
Characterize the Nature and Extent of Contamination	
1) Determine the horizontal and vertical extent of surficial radionuclide soil contamination due to wind dispersion	- Collect surficial soil scrapes in the study area following Colorado Department of Health sampling procedures and analyze for radionuclides - Sample vertical soil profiles and analyze for radionuclides

TABLE 3-1 (continued)
PHASE III RFI/RI OBJECTIVES AND ACTIVITIES

Objective	Activity
2) Determine the nature and extent of ground-water contamination in surficial materials	- Install alluvial ground-water monitoring wells in surficial materials located between areas of known ground-water contamination and areas with no ground-water contamination to delineate the extent Collect ground-water samples and analyze for TCL volatiles, semi-volatiles and pesticides/PCBs, TAL metals, radionuclides, and inorganics
3) Determine the location and extent of weathered and unweathered sandstone units and associated contamination	- Install bedrock monitoring wells in new boreholes in which sandstones are encountered This will include boreholes which were initially planned for installing alluvial wells, as well as selected boreholes planned specifically to seek sandstone Produce east-west and north-south geologic and water-level cross-sections as data permit Collect ground water samples and analyze for TCL volatiles, semi-volatiles and pesticides/PCBs, TAL metals, radionuclides and inorganics
4) Characterize surface water quality	- Continue collection of surface water from existing monitoring stations on a quarterly basis Establish sediment stations directly associated with the 881 Hillside as sediment availability permits Analyze samples for TCL volatiles, TAL metals, radionuclides, and inorganics Analyze surface water samples for both dissolved and total metals and radionuclides to determine if constituents are suspended or dissolved Continue routine flow rate measurements at surface water stations
Provide A Baseline Risk Assessment	
1) Describe contaminant fate and transport	- Use existing literature and field data to describe the physicochemical processes associated with site contaminants Incorporate Phase III results into risk analysis
2) Assess the threat to public health and the environment from the no action remedial alternative	- Prepare a baseline risk assessment as part of the RI data analysis based on Phase I, II, and III RI

SECTION 4

REMEDIAL INVESTIGATION/FEASIBILITY STUDY TASKS

4 1 REMEDIAL INVESTIGATION TASKS

4 1 1 Task 1 - Project Planning

The project planning task includes all efforts required to initiate this Phase III RFI/RI of Operable Unit No 1 Activities undertaken for this project have included detailed review of the Phase I and II RI results, responses to EPA comments on the FS and Phase II RI (Rockwell International, 1989a), responses to DOE comments on the FS, responses to EPA and CDH comments on the draft RI/FS work plan, historical aerial photography, preliminary results of the high resolution seismic reflection program, and preliminary evaluation of ARARs Results of these activities are presented in Sections 1 (Introduction) and 2 0 (Phase I and Phase II Site Evaluation)

Two project planning documents, including this Work Plan, have been prepared which pertain to this Phase III RFI/RI as required by the draft IAG between DOE, EPA, and CDH This Work Plan presents results of the project planning task in addition to plans for the Phase III RFI/RI A Field Sampling Plan (Section 5) presents the locations, media, and frequency of sampling efforts The second document required by the IAG is a Sampling and Analysis Plan (SAP) The IAG specifies that the SAP is to include a QAPjP and SOP for all field activities A draft QAPjP for site-wide RCRA and CERCLA activities (EG&G, 1990d) was submitted to the regulatory agencies in August 1990 A GRRASP (EG&G, 1990e) has also been prepared which is the scope of work for analytical services The current Rocky Flats Plant SOPs were submitted to EPA and CDH in August 1990 (EG&G, 1990c) A Health and Safety Plan (HSP) defining the protocol for protection of field workers during Phase III operations will be submitted as well The HSP will be based on the Health and Safety Program Plan currently being finalized based on comments from EPA and CDH

4 1 2 Task 2 - Community Relations

In accordance with the draft IAG, the Rocky Flats Plant is developing a Community Relations Plan to inform and actively involve the public in decision-making regarding environmental restoration activities The plan will address the needs and concerns of the surrounding communities as identified through approximately 80 interviews with state and local elected officials, business leaders, medical professionals, educational representatives, interest groups, media and residents adjacent to the Plant.

The draft Community Relations Plan will be submitted to EPA and CDH for review in November 1990 in accordance with the draft IAG schedules Accordingly, the site-specific Community Relations Plan is not required for Operable Unit No 1 Following review by EPA and CDH, the plan will be distributed for public review and comment in January 1991

During the February 1990 public hearing on the IAG, several commentors requested the development of an Interim Community Relations Plan for implementation until the final plan is available in mid-1991 This draft Interim Community Relations Plan was prepared and will be implemented by November 1990

Current ER Program community relations activities include participation by Plant representatives in informational workshops, meetings of the Rocky Flats Environmental Monitoring Council, briefings for citizens, businesses and surrounding communities on environmental restoration and monitoring activities, and public comment meetings on various ER Program plans and actions

The Rocky Flats Plant continues additional efforts to inform the public of environmental restoration activities and other issues that relate to Plant operations A Speakers Bureau provides Plant speakers to civic groups and educational organizations, and a Public Tours program allows the public to visit the Rocky Flats Plant The Plant also produces fact sheets and updates on environmental restoration activities for public information and responds to numerous public inquiries concerning the Plant

4 1 3 Task 3 - Field Investigation

The Phase III RFI/RI field investigation is designed to meet the objectives outlined in Section 3 The following activities will be performed as part of the field investigation

- Drill and sample soils and wastes within IHSSs,
- Install and sample ground-water monitoring wells,
- Perform aquifer tests and geotechnical tests, and
- Collect surface water and sediment samples

Sample locations, frequency, and analyses are presented in Section 5 All field activities will be performed in accordance with the Rocky Flats Plant ER Program SOP and QAPjP

4 1 4 Task 4 - Sample Analysis and Data Validation

Analytical methods for chemical analyses are provided in the GRRASP (EG&G, 1990e) Also provided in this document are the analytical detection limits

Data will be reviewed and validated by the EG&G Environmental Monitoring and Assessment Division laboratory validation subcontractor Results of data review and validation activities will be documented in data validation reports EPA data validation functional guidelines will be used for validating organic and inorganic (metals) data (U S EPA, 1988a) Validation methods for radiochemistry and major ions data have not been published by the EPA, however, data and documentation requirements have been developed by ER Department The functional guidelines which will be used to evaluate analytical data are presented in the QAPjP (EG&G, 1990d) and GRRASP (EG&G, 1990e)

4 1 5 Task 5 - Data Evaluation

Data collected during the Phase III RFI/RI will be incorporated into the existing database and used to better define site characteristics, source characteristics, the nature and extent of contamination These data will then be used during the FS to support the evaluation of proposed remedial alternatives

4 1 5 1 Site Characterization

Geologic and hydrologic data will be incorporated into existing site maps and cross sections Geologic data will be used to detail the stratigraphy of surficial materials and weathered bedrock within source areas and to map the eastern extent of paleochannels in the top of bedrock Hydrologic data will be used to evaluate seasonal variations in water levels, ground-water flow, and the extent of saturated surficial materials Also evaluated will be hydraulic conductivity, storage coefficient, ground-water velocity, and the interaction between ground water and surface water

4 1 5 2 Source Characterization

Analytical data from source boreholes will be used to

- Verify IHSS locations,
- Characterize the nature of source contaminants,
- Characterize the lateral and vertical extent of source contaminants,
- Determine the maximum on-site contaminant concentrations, and
- Quantify the volume of source materials

4 1 5 3 Nature and Extent of Contamination

Analytical data from soil, sediment, ground-water, and surface water sampling efforts will be used to characterize the nature and extent of contamination The criteria for the identification of contamination will be analyte specific For organic compounds, any detectable concentrations in samples that are not attributable to laboratory contamination [defined according to CLP protocol (U S EPA, 1988b)] will be considered likely evidence of contamination For inorganic compounds (including radionuclides) only those concentrations which exceed expected concentrations in background shall constitute evidence of contamination The statistical techniques which shall be used to compare concentrations of inorganic compounds collected as part of the Phase III RFI/RI to background concentrations are documented in the Background Geochemical Characterization Report (Rockwell International, 1989d) Essential to the implementation of these statistical techniques for ground-water and borehole samples is the classification of each analytical datum by an appropriate geologic unit (such as Rocky Flats Alluvium or colluvium) This identification of the appropriate geologic unit will be based on geological data collected during the Phase III RFI/RI

The extent of contamination will be delineated through the use of contaminant isopleths maps and possibly cross sections The possibility of using kriging to contour the isopleths of the most widely distributed contaminants will be investigated with explicit attention to the assumptions required by kriging (Davis, 1986), and kriged contours will be generated only if appropriate Investigations to date indicate difficulty in identifying the source of contamination because of the close proximity of several possible sources The statistical technique of principal component analysis will be investigated as a method of identifying the releases from different sources The ability to estimate the individual effects of multiple sources at intermediate sampling sites will aid in the mapping of plumes and in the understanding of contaminant transport by the ground-water flow system

Comparisons of analytical data from ground water and surface water will be made to investigate the movement of contaminants from one pathway to another Temporal variations of contaminant concentrations in ground water and surface water will be evaluated both for seasonality and long-term trends to determine contaminant migration rates

Analytical data from surficial soil scrapes and vertical soil profiles will be evaluated in order to characterize the areal and vertical distribution of plutonium and americium contamination at the 881 Hillside Area

4 1 6 Task 6 - Baseline Risk Assessment

A baseline risk assessment will be prepared for the 881 Hillside Area as part of the Phase III RFI/RI to evaluate the potential threat to the public health and the environment in the absence of remedial action A risk assessment was previously prepared as part of the draft FS (Rockwell International, 1988b) The baseline risk assessment will evaluate data collected during Phase III and use information, as appropriate, developed in the original risk assessment The baseline risk assessment will provide the basis for determining whether or not remedial action is necessary in the area and serve as the justification for performing remedial action (U S EPA, 1988b)

Several objectives will be accomplished under the risk assessment task including identification and characterization of the following (U S EPA, 1988b)

- toxicity and levels of hazardous substances present in relevant media (e g , air, ground water, soil, surface water, sediment, and biota),
- environmental fate and transport mechanisms within specific environmental media such as physical, chemical, and biological degradation processes and hydrogeological conditions,
- potential human and environmental receptors,
- potential exposure routes and extent of actual or expected exposure,
- extent of expected impact or threat, and the likelihood of such impact or threat occurring (i e , risk characterization), and
- level(s) of uncertainty associated with the above

The public health risk assessment and the environmental evaluation will be performed in accordance with EPA and other guidance documents listed in Table 4-1 The risk assessment will address the potential public health and environmental impacts associated with the site under the no-action alternative (no remedial action taken) This assessment will aid in the selection of site remedies based on the contaminants of concern and the environmental media associated with potential risks to public health and the environment

4 1 6 1 Public Health Evaluation

The risk assessment process is divided into four tasks (U S EPA, 1988b), including

- Contaminant identification,
- Exposure assessment,
- Toxicity assessment, and
- Risk characterization

The task objectives and description of work for each task are described below

TABLE 4-1

EPA GUIDANCE DOCUMENTS WHICH WILL BE USED IN THE RISK ASSESSMENT TASK

- Risk Assessment Guidance for Superfund, Human Health Evaluation Manual Part A, Interim Final (U S EPA, 1989a)
- Superfund Exposure Assessment Manual (U S EPA, 1988c)
- Exposure Factors Handbook (U S EPA, 1989b)
- The Endangerment Assessment Handbook (U S EPA, 1985)
- CERCLA Compliance With Other Laws Manual (U S EPA, 1988d)
- Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA (U S EPA, 1988b)
- Ecological Assessment of Hazardous Waste Sites A Field and Laboratory Reference (U S EPA, 1989c)
- Risk Assessment Guidance for Superfund -- Environmental Evaluation Manual (U S EPA, 1989d)
- Data Quality Objectives for Remedial Response Activities Development Process (U S EPA, 1987)
- EPA's Integrated Risk Information System (IRIS) (U S EPA, continuously updated)
- Health Effects Assessment Summary Tables (HEAST) (U S EPA, updated quarterly)
- Office of Solid Waste and Emergency Response (OSWER) Directive on Soil Ingestion Rates (U S EPA, 1989e)
- Superfund Risk Assessment Information Directory (RAID) (U S EPA, under revision)

Contaminant Identification

The objective of contaminant identification is to screen the information that is available on hazardous substances or wastes present at the site and to identify contaminants of concern to focus subsequent efforts in the risk assessment process Previous work characterizing aspects of the Rocky Flats Plant and the surrounding area has been done Additional sampling and analysis of various media will take place in order to support the human health risk assessment, the ecological assessment and to characterize the site For thisrisk assessment, all chemicals detected above background concentrations in site-associated media at Operable Unit No 1 will be treated as site contaminants for the purpose of public health evaluation These include

- Chemicals positively identified in one or more samples in a given medium,
- Chemicals which have been tentatively identified and have historically been associated under the site or confirmed by special analysis

The potential transformation products of site-associated chemicals will be considered to the extent possible by the availability of chemical-specific transformation data and information regarding site specific environmental conditions (e g , potential for biodegradation)

All chemicals present below background will be eliminated from further consideration In addition, after the completion of the exposure assessment, any site contaminants which appear to have no potential for exposure will not be evaluated All chemicals that are deleted and the rationale for their deletion will be discussed

Exposure Assessment

The objectives of the exposure assessment are to identify actual or potential exposure pathways, to characterize potentially exposed populations, and to determine the extent of exposure An exposure pathway is comprised of four elements

1) a source and mechanism of chemical release to the environment,

2) an environmental transport medium or media (e g , air, ground water) for the released constituent,

3) a point of potential contact of humans or biota with an affected medium (the exposure point), and

4) an exposure route (e g , inhalation of contaminated dust) at the exposure point

The exposure assessment process will include the following actions

- analyze the probable fate and transport of compounds for both the present and the future uses,
- identify the human populations in the area, typical activities that would influence exposure, and sensitive population subgroups,
- identify potential exposure pathways under current and future land use conditions,
- develop exposure scenarios for each identified pathway and select those scenarios that are plausible,
- identify scenarios assuming both existing and potential future uses, and
- identify the exposure parameters to be used in assessing the risk for all scenarios

Appropriate exposure scenarios will be identified for the site based on current and future receptor subpopulations, including residents Another subpopulation which could potentially be considered is on-site workers Factors to be examined in the pathway and receptor identification process will include

- Location of contaminant source,
- Local topography,
- Meteorology,
- Local geohydrology/surface water hydrology,
- Surrounding land use,
- Local water use,
- Prediction of contaminant migration, and
- Persistence and mobility of migrating contaminants

For each migration pathway and for current and future conditions, receptors will be identified and characterized Potential receptors will be defined by the appropriate exposure scenarios

To assess the potential adverse health effects associated with access to the site, the potential level of human exposure to the selected chemicals must be determined Intakes of exposed populations will be calculated separately for all appropriate pathways of exposure to chemicals Then for each population-at-risk, the total chronic intake by each route of exposure will be calculated by adding the intakes from each pathway Total oral, inhalation, and dermal chronic exposures will be estimated separately Chronic daily intakes will be calculated based on the upper 95 percent confidence limit of the exposure data

In general, chemical intakes will be estimated using available region-specific exposure parameters developed by the EPA. Any deviation from these parameters will be documented and submitted to the regional EPA office for approval prior to preparation of the risk assessment

Toxicity Assessment

In accordance with EPA's risk assessment guidelines, the projected concentrations of all chemicals above background at exposure points will be compared with ARARs to judge the degree and extent of risk to public health and the environment (including plants, animals, and ecosystems) Because many ARARs do not exist for certain media (such as soils) nor are all ARARs necessarily health based, this comparison is not sufficient in itself to satisfy the requirements of the risk assessment process Moreover, receptors may be exposed to contaminants from more than one medium so that their total doses might exceed risk reference doses (RfDs) and/or might result in an excess cancer risk greater than an acceptable target risk as defined by EPA (i e , 10^{-6} to 10^{-4}) Nevertheless, the comparison with standards and criteria is useful in defining the exceedance of institutional requirements Aside from the ARARs listed in Table 2-13, the following criteria will be examined

- drinking water health advisories,
- ambient water quality criteria for protection of human health,
- Center for Disease Control and Agency for Toxic Substances and Disease Registry soil advisories, and
- National Ambient Air Quality Standards

Critical toxicity values (i e , numerical values derived from dose-response information for individual compounds) will be used in conjunction with the intake determinations to characterize risk Toxicity reference values from EPA's Integrated Risk Information System (IRIS) will be used in preference to other EPA reference values

A summary of any toxicological studies performed will be provided for all chemicals above background in the baseline risk assessment The quality of these studies and their usefulness in estimating human health risks will be described A more detailed explanation of the toxic effects of target chemicals will be provided in the appendices to the human health risk assessment and the environmental evaluation Toxicity reference values will also be summarized For the human health risk assessment, this will include a brief description of the studies upon which selected reference values were based, the uncertainty factors used to calculate RfDs, and the EPA weight-of-evidence classification for carcinogens For those chemicals without EPA toxicity reference values, a literature search, including computer data bases, will be conducted for selected chemicals A toxicity value will then if possible, be derived from this information EPA and CDH will be consulted regarding the appropriateness of the data and the methodologies to be used in deriving reference values Uncertainties regarding the toxicity assessment will be discussed

Two different types of critical toxicity values will be used

- Risk reference doses (RfDs) for chronic exposure, and
- the carcinogenic potency factor (for carcinogenic chemicals only)

Risk Characterization

Risk characterization involves integrating exposure assumptions and toxicity information to quantitatively estimate the risk of adverse health effects Risk characterization will be performed in accordance with EPA guidance

Noncarcinogenic risk will be evaluated by comparison of contaminant intakes at exposure points to chronic reference doses for protection of human health Carcinogenic risk will be quantified using carcinogenic potency factors Risk will be qualitatively evaluated for those contaminants for which quantitative evaluation is not possible

An uncertainty analysis will be performed to identify and evaluate non-site and site specific factors that may produce uncertainty in the risk assessment, such as assumptions inherent in the development of toxicological endpoints (potency factors, reference doses) Moreover, site-specific factors which may produce uncertainty will also be discussed

The results of the baseline risk assessment will be used to define and evaluate the remedial alternatives during the FS

4 1 6 2 Environmental Evaluation

The objective of the environmental evaluation for Operable Unit No 1 is to determine if the contaminants have caused or are causing any adverse environmental impact Data will be collected to help determine the bio availability of contaminants to terrestrial and aquatic flora and fauna surrounding the site That information, and data on the habitats and key ecological endpoints for those habitats will subsequently be used in the ecological risk assessment A separate environmental evaluation work plan has been prepared by EG&G and is presented in Section 6 which specifies more detailed plans for the environmental evaluation

The environmental evaluation will be conducted according to guidance in the "Risk Assessment Guidance for Superfund", Volume II, Environmental Evaluation Manual (U S EPA, 1989d) Previous studies, including a radioecology study (Rockwell International, 1986f) and a Final Environmental Impact Statement (U S DOE, 1980), as well as soils, sediment, and surface water chemical data and other biologically-important parameters measured during other components of this RI, will be used to assess current and future ecological impacts from Operable Unit No 1 Additional field and laboratory activities planned for this investigation will be necessary to determine what effect contaminants at the 881 Hillside Area are having on the area's flora and fauna This will include tissue analyses of selected species to assess the exposure of these potential receptors to site contaminants Field assessments of community organization, and the use of biomarkers where applicable (e g reproductive success studies) will supplement these data

Field surveys of aquatic invertebrates in Woman Creek and terrestrial organisms found within the 881 Hillside Area will be conducted to determine if these organisms have been adversely affected by contaminants at the site The aquatic survey will include an evaluation of biomass, relative abundance, species richness, and community evenness The upper reaches of Woman Creek will be evaluated for use as a reference area for comparing results from the site survey Similarity between stations will be evaluated using statistically appropriate indices (Sorenson and/or Jaccard coefficients and Van Horn Index of Similarity)

In addition to the study of direct impacts on the macroinvertebrates using the stream as primary habitat, the potential for indirect effects on wildlife using the surface water for feeding and drinking will be evaluated to the extent data allow The terrestrial survey will estimate numbers of resident species, and make note of their food habits This information will be used to develop food web models and exposure-receptor pathway models to evaluate the transport of contaminants from the 881 Hillside Area to biological receptors

Estimates of toxicity in environmental media may be either chemistry- or toxicity-based A chemistry-based approach will include comparison of on-site water, air, soil, and/or sediment analyses with available literature data to estimate toxicity For this evaluation toxicological endpoints for indicator or target species will be chosen based on a review of available laboratory toxicity tests providing quantitative data for species of concern In the absence of toxicological indices for the target species, toxicological endpoints will be derived using safety factors that reflect interspecies extrapolation, acute-to-chronic extrapolations, and added protection for endangered and/or threatened species If this analysis fails to explain the contaminant impact on biota, the toxicity-based approach may be used This approach involves measurements of the biological effects associated with exposure to complex mixtures Toxicity testing generally includes the use of acute and chronic toxicity methods

Biochemical or physiological responses (biomarkers) in individual organisms can provide sensitive indices of exposure or sublethal stress The evaluation of biomarkers can therefore provide an understanding of the dynamics of community structure, such as abundance, diversity and nutrient utilization Biomarkers for sublethal stress include overt symptomology such as skeletal abnormalities (lordosis, scoliosis), gas exchange in plants, and measurable processes at the cellular and molecular level such as enzyme function Examples

Biochemical or physiological responses (biomarkers) in individual organisms can provide sensitive indices of exposure or sublethal stress The evaluation of biomarkers can therefore provide an understanding of the dynamics of community structure, such as abundance, diversity and nutrient utilization Biomarkers for sublethal stress include overt symptomology such as skeletal abnormalities (lordosis, scoliosis), gas exchange in plants, and measurable processes at the cellular and molecular level such as enzyme function Examples of biomarkers that may be considered for this assessment include microbial bioassay (microtox) and enzyme function in small mammals [amino-lerulinic acid dehydrase (ALAD)] Procedures to be used for the field and laboratory activities are presented in the "Ecological Assessment of Hazardous Waste Sites A Field and Laboratory Reference (U S EPA, 1989c)

Conclusions of the environmental evaluation will be presented along with a discussion of the success in meeting the study objectives and of the sources and degree of uncertainty in reaching those conclusions

4 1 7 <u>Task 7 - Treatability Studies/Pilot Testing</u>

A draft Treatability Studies Plan (TSP) (EG&G, 1990f) was prepared and submitted to the regulatory agencies in September 1990 in accordance with the draft IAG schedule This document provides comprehensive plans for treatability studies designed for remediation of waste sources, soils, and water at all operable units at Rocky Flats Plant The Treatability Studies Program that is addressed by the TSP will serve to determine the operability, reliability, cost-effectiveness, and overall implementability of technologies that are appropriate for the types of contaminants and contaminated media at the Plant but are not adequately proven

The Treatability Studies Program is divided into two components which separately address practical (i e , conventional) technologies and innovative/emerging technologies The separation of the two programs allows immediate start on the testing of practical technologies and provides a framework for addressing emerging technologies as they become available The TSP identifies practical technologies that are applicable to the Rocky Flats Plant contamination, screens these technologies to determine candidates for treatability studies, and provides statements of work for each candidate treatability study Subsequently, work plans will be prepared for conduct of the treatability studies The treatability studies will then be performed, and a

TABLE 4-2

TECHNOLOGIES IDENTIFIED FOR TREATABILITY STUDIES

Inorganics, Radionuclides, and Metals

Oxidation/Reduction and appropriate separation

Inorganics, Radionuclides, and Metals in Soil

Physical Separation (screening, classification, flotation, gravity concentration)

Soil Washing (water, acid, chelating agents)

Solidification/Stabilization (silicate-based, pozzolanic-based)

Organics in Soil

Biological Treatment (bench-scale for semivolatiles)

Practical Treatability Studies Report (draft report due in May 1993) may not permit full utilization of this information for the Operable Unit No 1 CMS/FS report (draft report due in March 1993) However, the draft IAG schedule for Operable Unit No 1 calls for scoping of treatability studies specific to Operable Unit No 1 beginning in February 1992, with studies completed by October 1992 During the scoping of treatability studies, the need to acquire additional data on the practical technologies as well as the need to conduct treatability studies for innovative/emerging technologies applicable to Operable Unit No 1 will be determined Work plans will be subsequently prepared, as appropriate

4 1 8 Task 8 - Remedial Investigation Report

A Draft Phase III RFI/RI Report will be prepared to consolidate and summarize the data obtained during Phases I, II, and III RI field work This report will

- Describe in detail the field activities which serve as a basis for the RI report This will include any deviations from the work plan which occurred during implementation of the field investigation
- Thoroughly discuss site physical conditions This discussion will include surface features, meteorology, surface water hydrology, surficial geology, ground-water hydrology, demography and land use, and ecology
- Present site characterization results discussing the nature and extent of contamination as well as contaminant migration rates The media to be addressed will include contaminant sources, soils, ground water, surface water, air, and biota All relevant quarterly ground water and surface water data collected at the plant will be used in this assessment
- Discuss contaminant fate and transport This discussion will include potential migration routes, contaminant persistence, and contaminant migration
- Present a baseline risk assessment The risk assessment will include human health and environmental evaluations
- Present a summary and conclusions

4 2 FEASIBILITY STUDY TASKS

A CMS/FS is planned for the 881 Hillside Area to evaluate remedial alternatives for clean up of contaminated soils, ground water, and surface water Results of the Phase III RFI/RI and baseline risk assessment will indicate to what extent other remedial action is necessary for Operable Unit No 1

As discussed in Section 2 5, the draft FS was incomplete in addressing the full extent and nature of contamination The organization of the draft report is also not consistent with more recent EPA guidance [Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA (U S EPA, 1988b)] This section describes the tasks to be performed that conform with the EPA guidance

The CMS/FS process occurs in two phases The first phase consists of developing and screening remedial alternatives, and the second phase includes a detailed analysis of alternatives (U S EPA, 1988b) Each of these two phases is discussed in the following sections

4 2 1 Task 9 - Remedial Alternatives Development and Screening

The goal of this task is to identify and screen remedial alternatives The work consists of four parts

- Identifying remedial technologies,
- Screening remedial technologies,
- Developing remedial alternatives, and
- Screening remedial alternatives

General response actions that may prove appropriate at the site were identified in Section 2 5 These general response actions were identified in order to determine data gaps to be addressed in RI activities For each response action, potentially applicable remedial technologies were identified These are also presented in Section 2 5 As the Phase III RFI/RI progresses, additional potentially applicable technologies may be determined

During screening, the broad expanse of potentially applicable technology types will be narrowed by eliminating those technologies that are not technically implementable Based on contaminant concentrations and other site-specific information contained in the Phase III RFI/RI, non-implementable technology types will be screened and eliminated from further consideration

Technology process options will then be screened in order to select a representative process option for each technology type that is technically implementable Process options are compared and eliminated based on their effectiveness relative to other processes within the same technology type The screening is based on the volume of media to be treated, achievement of remediation goals, potential impacts on human health and the environment, and the proven performance and reliability of the option considering the contaminants and site characteristics In addition to effectiveness, the process options will also be evaluated based on administrative feasibility and relative cost

To develop alternatives, general response actions and the process options that are representative of the various technology types for each medium will be combined to form alternatives for the operable unit In general, more than one response action is applicable to each medium Response actions and process options will be assembled based primarily on medium-specific considerations and implementability Descriptions of each alternative will be developed for inclusion in the CMS/FS report

During alternative screening, the developed alternatives will be evaluated to ensure that they protect human health and welfare and the environment from each potential pathway of concern at the operable unit Treatment rates will be identified, and the size and configuration of on-site extraction and treatment systems or containment structures will be developed The time frame in which treatment, containment or removal goals can be achieved will be determined Lastly, spatial requirements for treatment units, containment structures, staging of construction materials, excavated wastes, etc will be determined If there are off-site actions such as surface water discharge, a regulatory review will be conducted to determine permit and compliance requirements

Alternatives will then be further defined to provide sufficient information to differentiate among alternatives with respect to effectiveness, implementability and cost Each alternative will be evaluated to determine its effectiveness in protecting human health and the environment, and in reducing toxicity, mobility or volume of hazardous wastes or contaminated media As a consequence of reducing the toxicity, mobility or volume, the inherent threats or risks associated with wastes are decreased

Implementability is a measure of both the technical and administrative feasibility of constructing, operating and maintaining a remedial action alternative It is used during screening to evaluate the combinations of process options with respect to the site-specific conditions Technical feasibility refers to the ability to construct, reliably operate and comply with action-specific (technology-specific) requirements in order to complete the remedial action Administrative feasibility refers to the ability to obtain required permits and approvals, to obtain the necessary services and capacity for treatment, storage and disposal of hazardous wastes, and to obtain essential equipment and technical expertise

Cost estimates for screening will be derived from cost curves, generic unit costs, vendor information, conventional cost estimating guides and prior estimates made for Rocky Flats and similar sites, with modifications made for Rocky Flats Plant conditions Absolute cost accuracy is not necessary The cost estimates for the alternatives however, will have the same relative accuracy for comparison and screening The cost estimating procedures used during screening are similar to those that will be used during the later detailed alternatives analysis The later detailed analysis however, will receive more in-depth and detailed cost estimates of the components of each alternative The screening cost estimates will include capital, operating, and maintenance costs The operating and maintenance costs will be calculated for the lifetime of the treatment unit operation at the site Present worth cost analysis will be used for alternatives in order to make the costs for the various alternatives comparable

Alternatives with the most favorable results from the composite evaluation will be retained for further scrutiny during the detailed analysis Not more than ten alternatives will be retained for detailed analysis (including containment and no action) At that time, it may be determined that additional site-specific information or technology-specific treatability studies are necessary for an objective detailed analysis Also, it will be necessary to identify and verify the action-specific ARARs that each respective alternative will be required to meet

4 2 2 Task 10 - Detailed Analysis of Remedial Alternatives

The detailed analysis is not a decision-making process, but it is the process of analyzing and comparing relevant information in order to select a remedial action Each alternative will be assessed against nine evaluation criteria, and the assessments will be compared to identify the key tradeoffs among the alternatives Assessment against the nine evaluation criteria is necessary for the CMS/FS and the subsequent Corrective Action Decision (CAD)/Record of Decision (ROD) to comply with the requirements of RCRA/CERCLA

4 2 2 1 Alternative Analysis Against Nine Evaluation Criteria

Overall Protection of Human Health and the Environment

The alternatives will be individually analyzed to determine if the alternative provides adequate protection of human health and the environment The protectiveness evaluation focuses on how the risks posed by each pathway are being eliminated, reduced or controlled by treatment, engineering or institutional measures

Compliance with ARARs

Each alternative will be analyzed to determine whether it will comply with all state and federal ARARs that have been identified The analysis will address compliance with chemical-specific, location-specific and action-specific ARARs If an alternative will not comply with an ARAR, the CMS/FS report will present the basis for justifying a waiver

Long-Term Effectiveness and Permanence

This criterion assesses the risks that are left at the site after the response objectives have been met The risks associated with any remaining untreated wastes or treatment residuals will be evaluated For each alternative, the magnitude of the residual risk, and the reliability and adequacy of the controls used to manage untreated wastes and treatment residuals will be addressed

Reduction of Toxicity, Mobility or Volume Through Treatment

This criterion evaluates the statutory preference of selecting remedial actions that permanently reduce toxicity, mobility, or volume of the hazardous materials Factors evaluated for each alternative will include the proposed treatment process and the materials treated, the quantity of materials to be treated or destroyed, and how the primary hazardous threat will be addressed, the estimated degree of the reduction in toxicity, mobility or volume that will be achieved, the extent to which the treatment will be irreversible, the type and quantity of treatment residuals that will remain following treatment, and a determination if the alternative will comply with the statutory preference for treatment

Short-Term Effectiveness

Short-term effectiveness refers to the effects an alternative may have during the construction and implementation phases until the cleanup objectives have been achieved Alternatives will be evaluated to determine the effects on human health and the environment during implementation Each alternative will be assessed against the following factors protection of the community and workers during the remedial action, environmental impacts, and the time required to achieve the remedial action objectives

Implementability

This criterion assesses the technical and administrative feasibility of implementing an alternative, and the availability of the necessary services and materials The following factors will be analyzed during the implementability assessment the technical feasibility of construction and operation, the reliability of the technology, the practicability of employing additional remedial actions, the ability to monitor the effectiveness of the remedial action, administrative coordination with other offices and agencies, the availability of adequate off-site hazardous (or mixed) waste treatment, storage and disposal, and the availability of equipment, expertise and other services and materials

Costs

An in-depth cost estimate will be conducted, and if necessary, a cost sensitivity analysis will be prepared to evaluate costing assumptions Capital costs include direct construction costs and indirect non-construction costs and overhead costs Operating and maintenance costs are incurred after construction in order to operate the remedial action on a continuous basis until the remedial action objectives have been achieved CMS/FS cost estimates are expected to be within an accuracy range of minus 30 percent to plus 50 percent If this accuracy cannot be achieved, it will be stated in the CMS/FS report

A cost sensitivity analysis may be conducted to determine the effect that specific cost assumptions have on the total estimated cost of an alternative The cost assumptions will be based on site-specific data, technological operating data, etc although the assumptions will be subject to varying degrees of uncertainty depending on the accuracy of the data

State Acceptance

This criterion addresses the state's administrative and technical issues and concerns with each of the alternatives

Community Acceptance

Community acceptance addresses the public's concerns and issues with each of the alternatives

4 2 2 2 Comparison of Alternatives

The CMS/FS report will contain a narrative discussion of each alternative's evaluation against the nine criteria The narrative will describe how each alternative addresses the technical treatability issues, long-term and short-term effectiveness, costs, protection of human health and the environment, compliance with ARARs, etc Once the alternatives have been described, a comparative analysis will be conducted to evaluate the relative performance of each alternative The relative advantages and disadvantages of each alternative with respect to the other alternatives will be determined in order to assess the key tradeoffs that must be made in selecting a remedial action A candidate alternative must generally attain the primary objectives of compliance with ARARs and overall protection of human health and the environment in order for it to be eligible for selection as the remedial action A narrative discussion of the alternatives comparison describing the tradeoffs, and the benefits and detriments of each alternative in comparison to the others will be included in the CMS/FS report

Following completion of the CMS/FS process, the results of the detailed alternatives comparison and risk management will be used as the rationale for selecting a preferred alternative and a remedial action Although the purpose of the CMS/FS report and process is not to select a remedial action, it will present and evaluate the alternatives in sufficient detail in order to objectively consider all significant issues and select a feasible, cost-effective and defensible remedial action

4 2 3 Task 11 - Feasibility Study Report

The CMS/FS Report will present the results of the feasibility study The report will include sections describing site background, nature and extent of problem, results of the RFI/RI, risk assessment and environmental evaluation, identification, screening and detailed evaluation of remedial alternatives, and the recommended remedial actions This task includes preparation of a Draft CMS/FS report, and preparation of a Final CMS/FS that incorporates EPA and CDH comments An outline for the CMS/FS report is shown in Table 4-3

TABLE 4-3

CMS/FS REPORT FORMAT

Executive Summary
1 Introduction
- 1 1 Purpose and Organization of Report
- 1 2 Background Information (summarized from RI Report)
  - 1 2 1 Site Description
  - 1 2 2 Site History
  - 1 2 3 Nature and Extent of Contamination
  - 1 2 4 Contaminant Fate and Transport
  - 1 2 5 Baseline Risk Assessment

2 Identification and Screening of Technologies
- 2 1 Introduction
- 2 2 Remedial Action Objectives
  Present the development of remedial action objectives for each medium of interest (i e , ground water, soil, surface water, air, etc)
  For each medium, the following should be discussed
  - Contaminants of interest
  - Allowable exposure based on risk assessment (including ARARs)
  - Development of remediation goals
- 2 3 General Response Actions
  For each medium of interest, describes the estimation of areas or volumes to which treatment, containment, or exposure technologies may be applied
- 2 4 Identification and Screening of Technology Types and Process Options - For each medium of interest, described
  - 2 4 1 Identification and Screening of Technologies
  - 2 4 2 Evaluation of Technologies and Selection of Representative Technologies

3 Development and Screening of Alternatives
- 3 1 Development of Alternatives
  Describes rationale for combination of technologies/media into alternatives Note This discussion may be by medium or for the site as a whole
- 3 2 Screening of Alternatives
  - 3 2 1 Introduction
  - 3 2 2 Alternative 1
    - 3 2 2 1 Description
    - 3 2 2 2 Evaluation
  - 3 2 3 Alternative 2
    - 3 2 3 1 Description
    - 3 2 3 2 Evaluation
  - 3 2 4 Alternative 3

4 Detailed Analysis of Alternatives
- 4 1 Introduction
- 4 2 Individual Analysis of Alternatives
  - 4 2 1 Alternative 1
    - 4 2 1 1 Description
    - 4 2 1 2 Assessment
  - 4 2 2 Alternative 2
    - 4 2 2 1 Description
    - 4 2 2 2 Assessment
  - 4 2 3 Alternative 3
- 4 3 Comparative Analysis

Bibliography

Appendices

TABLE 4-3

CMS/FS REPORT FORMAT

Executive Summary

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2 Identification and Screening of Technologies
- 2 1 Introduction
- 2 2 Remedial Action Objectives

  Present the development of remedial action objectives for each medium of interest (i e , ground water, soil, surface water, air, etc)

  For each medium, the following should be discussed
  - Contaminants of interest
  - Allowable exposure based on risk assessment (including ARARs)
  - Development of remediation goals
- 2 3 General Response Actions

  For each medium of interest, describes the estimation of areas or volumes to which treatment, containment, or exposure technologies may be applied
- 2 4 Identification and Screening of Technology Types and Process Options - For each medium of interest, described
  - 2 4 1 Identification and Screening of Technologies
  - 2 4 2 Evaluation of Technologies and Selection of Representative Technologies

3 Development and Screening of Alternatives
- 3 1 Development of Alternatives

  Describes rationale for combination of technologies/media into alternatives Note This discussion may be by medium or for the site as a whole
- 3 2 Screening of Alternatives
  - 3 2 1 Introduction
  - 3 2 2 Alternative 1
    - 3 2 2 1 Description
    - 3 2 2 2 Evaluation
  - 3 2 3 Alternative 2
    - 3 2 3 1 Description
    - 3 2 3 2 Evaluation
  - 3 2 4 Alternative 3

4 Detailed Analysis of Alternatives
- 4 1 Introduction
- 4 2 Individual Analysis of Alternatives
  - 4 2 1 Alternative 1
    - 4 2 1 1 Description
    - 4 2 1 2 Assessment
  - 4 2 2 Alternative 2
    - 4 2 2 1 Description
    - 4 2 2 2 Assessment
  - 4 2 3 Alternative 3
- 4 3 Comparative Analysis

Bibliography

Appendices

SECTION 5

PHASE III RFI/RI FIELD SAMPLING PLAN

The overall objectives of the Phase III RFI/RI are source characterization and better definition of the nature and extent of soils, alluvial ground water, bedrock ground water, and surface water contamination Within these broad objectives, site specific data objectives and needs have been identified in Section 3 The purpose of this section is to provide a detailed field sampling plan which will satisfy these data objectives and needs

All field operations will include appropriate measures to protect the environment and field workers as specified in the Operational Safety Analysis document prepared by EG&G (1989) The most current version of this document will be consulted at the time field operations begin Such precautions may include, for example, pre-drilling screening for radionuclide and other hazards, containerization of drill cuttings and/or ground water that is removed from wells for pre-sample purging, and monitoring and/or mitigation of ambient air hazards during field work

5 1 SOURCE CHARACTERIZATION

Further source characterization is required for sites within Operable Unit No 1 Boreholes will be drilled into IHSSs to characterize any waste materials remaining in place and to assess the maximum contaminant concentrations in soils directly beneath the sites In addition, ground-water monitoring wells will be installed adjacent to some of the boreholes to characterize ground-water quality directly beneath the sites This section discusses those wells and boreholes which will be drilled for source characterization Wells to be drilled outside of IHSSs for characterizing the extent of contamination are discussed in Section 5 1 2 All proposed Phase III RFI/RI wells are shown on Figure 5-1 Drilling, sampling, and well installation will follow the Rocky Flats Plant ER Program SOP (EG&G, 1990c)

Boreholes to be drilled into IHSSs will extend from the ground surface to the base of weathered bedrock Continuous samples will be collected for geologic descriptions for the entire borehole depth From this core, discrete samples will be submitted for laboratory chemical analyses every two feet from the ground surface to the water table In addition, a discrete sample will be submitted for laboratory chemical analysis if staining, discoloration, or odor is observed during drilling A discrete sample will also be collected for chemical analysis at the water table Core from saturated surficial materials will not be submitted to the laboratory, as the presence of water in this zone will affect interpretation of chemical results In order to prevent alluvial ground water from affecting weathered bedrock samples, surface casing will be grouted into the borehole through surficial materials Subsequent to grout hardening, the borehole will then be advanced through weathered bedrock with continuous sampling Discrete samples from the core will be submitted to the laboratory for chemical analysis from two feet immediately below the casing and every four feet thereafter to the base of weathering To further characterize weathered bedrock immediately beneath the sites, fracture patterns (both degree of fracturing and vertical extent) will be noted on the borehole logs and in situ packer tests will be performed in the bedrock where drilling conditions allow

Alluvial ground-water monitoring wells will be installed adjacent to some boreholes to characterize ground-water quality directly beneath IHSSs In addition, bedrock wells will be installed adjacent to boreholes where weathered sandstone is encountered to evaluate the potential downward migration of contaminants Wells will be drilled, sampled, and completed in accordance with the Rocky Flats Plant ER Program SOP (EG&G, 1990c) Source characterization borehole and monitor well locations are discussed in the following sections

5 1 1 Sample Locations

5 1 1 1 Oil Sludge Pit Site (IHSS Ref No 102)

The location of IHSS 102 has been revised from that shown in the Phase II RI report (Rockwell International, 1988a) based on further review of historical aerial photographs Specifically, the Oil Sludge Pit Site appears on a 1955 aerial photo Also evident on the 1955 photos is seepage from the pit as shown on Figure 5-1 The pit was covered after its use (Rockwell International, 1987c), and it is no longer visible on 1959 aerial photographs Additional soil and ground-water sampling are needed within, surrounding, and downgradient of IHSS 102 to document its location and to evaluate the nature and extent of potential contamination downgradient of the site

Two borings are proposed within this site to document its presence and location (Figure 5-1) Boreholes BH01 and BH02 will be drilled and sampled within the revised site location to identify the nature and maximum concentration of any contaminants associated with IHSS 102 Colluvial monitor well MW01 will be completed adjacent to BH01 to monitor ground-water quality directly beneath the site

In order to assess the nature and extent of soil and ground-water contamination downgradient of the Oil Sludge Pit Site, five boreholes are proposed in the area of staining directly south of the site Boreholes BH03, BH04, and BH05 will all be drilled and sampled within the area of seepage from IHSS 102 identified on 1955 aerial photographs A colluvial monitor well (MW02) will also be installed adjacent to borehole BH04 to assess ground-water flow directions and quality in this area Boreholes BH06 and BH07 are proposed downgradient of the seepage area to assess the extent of soil contamination As the proposed french drain at the 881 Hillside is upgradient of the apparent seepage from IHSS 102, boreholes BH03, BH05, and BH06 will be drilled and sampled during the french drain drilling program to evaluate its proposed alignment (Section 5 3)

Additional boreholes are proposed within and surrounding the former retention pond along Woman Creek to characterize soil and ground-water conditions in this area Two boreholes (BH08/MW33 and BH09) will be drilled within the former pond location, and two alluvial monitor wells (MW03 and MW33) are proposed south and southwest of the former pond These wells will serve to characterize the Woman Creek valley fill alluvial ground water downgradient of IHSS 102

5 1 1 2 Chemical Burial Site (IHSS Ref No 103)

No boreholes or monitor wells were installed directly within IHSS 103 during previous investigations Additional drilling and sampling are thus needed to characterize this site Three boreholes (BH10, BH11, and BH12) are proposed within the IHSS to identify the nature and maximum concentration of potential contaminants A colluvial monitor well (MW04) will be completed adjacent to BH10 to characterize ground water directly beneath the site, and colluvial monitor well MW05 will characterize ground-water quality immediately downgradient of the site The exact location of MW05 should be evaluated at the commencement of the drilling program to incorporate all available data on the potentiometric surface in that vicinity

5 1 1 3 Liquid Dumping Site (IHSS Ref No 104)

A site east of Building 881 was reportedly used for disposal of unknown liquids and empty drums prior to 1969 (U S DOE, 1986) The site was located as shown on Figure 5-1 by Rockwell International (1987c) based on 1965 aerial photographs, however, further review of these photographs indicates this site may be a shadow on the photo. Based on their description, it is suspected that IHSSs 103 and 104 are actually the same site However, the Phase III RFI/RI will include sampling and analysis of soils at the originally reported Liquid Dumping Site location to document its presence or lack thereof Two boreholes will be drilled within this reported IHSS location (BH13 and BH14)

5 1 1 4 Out-of-Service Fuel Oil Tanks (IHSS Ref Nos. 105 1 and 105 2)

These two sites were effectively taken out of service in 1976 This is presumably when they were filled with asbestos containing materials and then with concrete As the materials inside the tanks are solidified, they do not pose an environmental hazard In addition, the tanks tested tight in 1973 when they were pressure tested However, in order to document the lack of soil contamination associated with these tanks, two adjacent boreholes (BH15 and BH16) and two downgradient boreholes (BH17 and BH18) are proposed

5 1 1 5 Outfall Site (IHSS Ref No 106)

The Outfall Site consists of a six inch diameter vitrified clay pipe which is an overflow line from the sanitary sewer sump in Building 887 Discharge from this pipe was observed in December 1977 (Rockwell International, 1987c), however, subsequent discharges have not been noted Phase III RFI/RI activities at this site will include verifying the connection between the outfall pipe and Building 887 (original reports of the discharge indicated this was a clean-up pipe for an overflow line from the Building 881 cooling tower) as well as soil and ground-water sampling downgradient of the outfall

In order to verify the source of IHSS 106, water will be introduced to the outfall pipe from the Building 887 sewer sump, and the outfall on the hillside will be observed for discharge If the water is observed at the outfall, then the Building 887 sewer sump is the source of IHSS 106, and measures will be taken to contain any future discharges. If the Building 887 sewer sump is not the source of IHSS 106, further review of construction drawings for Buildings 881 and 887 and discussions with Plant personnel will be needed to identify the source of this outfall

Soil and ground-water contamination may exist downgradient of the Outfall Site due to previous releases from the site In order to characterize any contamination, two boreholes (BH19 and BH20) will be drilled and sampled immediately below the outfall A colluvial monitor well (MW06) will be installed adjacent to borehole BH19 to evaluate ground-water quality beneath the outfall

5 1 1 6 Hillside Oil Leak Site (IHSS Ref No 107)

The Hillside Oil Leak Site was originally designated as an IHSS because of an oil leak at this location in May, 1973 (Rockwell International, 1987c) It was later discovered that the oil had emerged through the Building 881 footing drain outfall, and a ditch and skimming pond were built to contain the oil (Owen and Steward, 1973) The skimming pond is still present, although, no oil has been observed in the outfall since 1973 (Rockwell International, 1987c) During the 881 Hillside Phase II RI, volatile organic compounds were detected in the outfall pipe discharge and in the skimming pond (Rockwell International, 1988a)

There are thus two issues associated with the Hillside Oil Leak Site

1) the nature and extent of soil and ground-water contamination potentially resulting from the original hillside oil leak, and

2) the source of volatile organic contaminants currently found in the Building 881 footing drain outfall

Two footing drains extend south from the Building 881 foundation (Figure 1-6) The western line joins the eastern line near the southeast corner of Building 885 This line then runs south where it daylights into the skimming pond The first step of this source investigation will consist of determining which of the two footing drains is the source of volatile organics at the footing drain outfall This will be accomplished by sampling the effluent in each footing drain line through a manhole located just south of their junction The line (or lines) responsible for contaminants at the outfall will then be sampled at clean-out points (if accessible) along its length to further isolate the contaminant source

Soil, ground-water, and surface water samples will be collected within IHSS 107 in order to characterize the nature and extent of contamination Soil samples will be collected from boreholes within the skimming pond Boreholes BH21 and BH22 are proposed and will be advanced to refusal using a hand auger MW17 will be installed to assess ground-water quality Routine surface water sampling will continue at stations SW-44 and SW-45

5 1 1 7 Multiple Solvent Spill Sites (IHSS Ref Nos 119 1 and 119 2)

IHSSs 119 1 and 119 2 were used from 1967 to 1972 for barrel storage Although the exact types and quantities of wastes stored at these sites are unknown, the barrels likely contained cutting oil wastes and solvents Spills and leaks from these drums likely occurred during the period of drum storage Barrel storage locations within the sites are shown on Figure 5-1

IHSS 119 1

A total of ten boreholes are proposed within the western barrel storage area to characterize the nature and extent of soil contamination associated with this site Boreholes BH23 through BH32 will be drilled and sampled within the drum storage areas as shown on Figure 5-1 In addition, colluvial monitor wells MW07, MW08, MW09, MW10, and MW11 will be installed to evaluate ground-water quality beneath the site and at the downgradient edge of the site

IHSS 119 2

Seven boreholes (BH33 through BH39) are proposed within the barrel storage areas of IHSS 119 2 to evaluate the nature and extent of potential soil contamination Monitor wells MW12 and MW13 will serve to monitor ground-water quality at the site's east-southeast downgradient edge

5 1 1 8 Radioactive Site No 1-800 Area (IHSS Ref No. 130)

This site was used to dispose of soil contaminated with low levels of plutonium between 1969 and 1972 Radionuclides were not above background levels in soil samples collected from this site during the Phase I and Phase II RIs However, additional soil samples will be collected from eight boreholes during the Phase III RFI/RI to verify this finding Boreholes BH40 through BH47 will be drilled and sampled through the site to assess the nature and extent of soil contamination In addition, colluvial monitor wells MW14, MW15, and MW16 will be installed adjacent to boreholes BH45, BH46, and BH47, respectively, to monitor water quality at the downgradient edge of this site

5 1 1 9 Sanitary Waste Line Leak Site (IHSS Ref No 145)

IHSS 145 is an area at the southeast corner of Building 881 where the sanitary sewer leaked in January 1981 No hazardous or radioactive constituents were released to the environment by this leak and the leak was repaired (Rockwell International, 1987c), so contamination is not expected at this site However, two boreholes BH48 and BH49 are proposed to check that indications of possible contamination in the nearby well 1-87 are not from this IHSS MW18 will also be installed to monitor ground water downgradient of the site

5 1 1 10 Building 885 Drum Storage Site (IHSS Ref No 177)

Building 885 is currently used for satellite collection and 90-day accumulation of RCRA regulated wastes A plan for soil sampling at this site is provided in the RCRA Interim Status Closure Plan which is appended to the revised Post-Closure Care Permit Application for Hazardous and Radioactive Mixed Wastes at the Rocky Flats Plant (Rockwell International, 1988d) Since ground water must be addressed under the RFI/RI program, a borehole (BH50) will be drilled downgradient from IHSS 177, and monitor well MW19 will be installed adjacent to BH50

5 1.2 SAMPLE ANALYSIS

5 1 2 1 Chemical Analysis of Soil Samples

Soil samples will be collected from boreholes within and adjacent to IHSSs to characterize sources. All samples will be analyzed for the chemical parameters listed in Table 5-1 following CLP methods or the methods specified in the GRRASP These parameters are essentially the same as those analyzed in the Phase I RI except that oil and grease and RCRA characteristics are eliminated Oil and grease have not proven useful in determining extent of soil contamination, and RCRA hazardous waste characteristics have been within acceptable limits. Total petroleum hydrocarbons were added to the analyte list for IHSSs 102 and 105 where fuel oil is a potential contaminant With a few exceptions, the TCL list for organics and the TAL list for inorganics are the same as the previously used HSL list for organics and inorganics The laboratory will be expected to analyze constituents to a detection limit at or below ARARs If that is not possible for some samples, the laboratory must provide a complete explanation for the reason(s)

5 1 2 2 Soil Blanks

Use of soil blanks is not necessarily standard protocol in the collection of soil samples for subsequent chemical analysis. In the Phase I and II RIs, methylene chloride, acetone, and phthalates appear to be contaminants in samples that were introduced through sample handling or sample analysis Soil blanks were not used in the previous investigation but appear necessary to confirm these findings An investigation will be designed to determine the source of phthalate contamination in soil samples and the need for soil blanks If appropriate, an alternative to previous field methods sampling will be implemented to avoid phthalate contamination from sampling handling in the future The laboratory will be expected to avoid contamination of samples with volatile organics and phthalates using appropriate procedures

TABLE 5-1

PHASE III RFI/RI
SOIL AND WASTE SAMPLING PARAMETERS

METALS

Target Analyte List - Metals

- Aluminum
- Antimony
- Arsenic
- Barium
- Beryllium
- Cadmium
- Calcium
- Chromium
- Cobalt
- Copper
- Iron
- Lead
- Magnesium
- Manganese
- Mercury
- Nickel
- Potassium
- Selenium
- Silver
- Sodium
- Thallium
- Vanadium
- Zinc

Other Metals

- Molybdenum
- Cesium
- Strontium
- Lithium
- Tin

INORGANICS

- pH
- Nitrate
- Percent Solids
- Sulfides

ORGANICS

Target Compound List - Volatiles

- Chloromethane
- Bromomethane
- Vinyl Chloride
- Chloroethane
- Methylene Chloride
- Acetone
- Carbon Disulfide
- 1,1-Dichloroethene
- 1,1-Dichloroethane
- total 1,2-Dichloroethene
- Chloroform
- 1,2-Dichloroethane
- 2-Butanone
- 1,1,1-Trichloroethane
- Carbon Tetrachloride
- Vinyl Acetate
- Bromodichloromethane
- 1,1,2,2-Tetrachloroethane
- 1,2-Dichloropropane
- trans-1,2-Dichloropropene

TABLE 5-1 (Continued)

PHASE III RFI/RI
SOIL AND WASTE SAMPLING PARAMETERS

ORGANICS (CONT.)

Target Compound List - Volatiles (Continued)

- Trichloroethene
- Dibromochloromethane
- 1,1,2-Trichloroethane
- Benzene
- cis-1,3-Dichloropropene
- Bromoform
- 2-Hexanone
- 4-Methyl-2-pentanone
- Tetrachloroethene
- Toluene
- Chlorobenzene
- Ethyl Benzene
- Styrene
- Total Xylenes
- 1,1-Dichloroethane

Other Organics

- Total petroleum hydrocarbons*

Target Compound List -- Semi-volatiles

- Phenol
- bis(2-Chloroethyl)ether
- 2-Chlorophenol
- 1,3-Dichlorobenzene
- 1,4-Dichlorobenzene
- Benzyl Alcohol
- 1,2-Dichlorobenzene
- 2-Methylphenol
- bis(2-Chloroisopropyl)ether
- 4-Methylphenol
- N-Nitroso-Dipropylamine
- Hexachloroethane
- Nitrobenzene
- Isophorone
- 2-Nitrophenol
- 2,4-Dimethylphenol
- Benzoic Acid
- bis(2-Chloroethoxy)methane
- 2,4-Dichlorophenol
- 1,2,4-Trichlorobenzene
- Naphthalene
- 4-Chloroaniline
- Hexachlorobutadiene
- 4-Chloro-3-methylphenol(para-chloro-meta-cresol)
- 2-Methylnaphthalene
- Hexachlorocyclopentadiene
- 2,4,6-Trichlorophenol
- 2,4,5-Trichlorophenol
- 2-Chloronaphthalene
- 2-Nitroaniline
- Dimethylphthalate
- Acenaphthylene
- 3-Nitroaniline
- Acenaphthene
- 2,4-Dinitrophenol
- 4-Nitrophenol
- Dibenzofuran
- 2,4-Dinitrotoluene
- 2,6-Dinitrotoluene

TABLE 5-1 (Continued)

PHASE III RFI/RI
SOIL AND WASTE SAMPLING PARAMETERS

ORGANICS (CONT.)
- Target Compound List -- Semi-volatiles (continued)
  - Diethylphthalate
  - 4-Chlorophenyl Phenyl ether
  - Fluorene
  - 4-Nitroaniline
  - 4,6-Dinitro-2-methylphenol
  - N-nitrosodiphenylamine
  - 4-Bromophenyl Phenyl ether
  - Hexachlorobenzene
  - Pentachlorophenol
  - Phenanthrene
  - Anthracene
  - Di-n-butylphthalate
  - Fluoranthene
  - Pyrene
  - Butyl Benzylphthalate
  - 3,3'-Dichlorobenzidine
  - Benzo(a)anthracene
  - bis(2-ethylhexyl)phthalate
  - Chrysene
  - Di-n-octyl Phthalate
  - Benzo(b)fluoranthene
  - Benzo(k)fluoranthene
  - Benzo(a)pyrene
  - Indeno(1,2,3-cd)pyrene
  - Dibenz(a,h)anthracene
  - Benzo(g,h,i)perylene
- Target Compound List -- Pesticides/PCBs
  - alpha-BHC
  - beta-BHC
  - delta-BHC
  - gamma-BHC (Lindane)
  - Heptachlor
  - Aldrin
  - Heptachlor Epoxide
  - Endosulfan I
  - Dieldrin
  - 4,4'-DDE
  - Endrin
  - Endosulfan II
  - 4,4'-DDD
  - Endosulfan Sulfate
  - 4,4'-DDT
  - Endrin Ketone
  - Methoxychlor
  - alpha-Chlordane
  - gamma-Chlordane
  - Toxaphene
  - AROCLOR-1016
  - AROCLOR-1221
  - AROCLOR-1232
  - AROCLOR-1242
  - AROCLOR-1248
  - AROCLOR-1254
  - AROCLOR-1260

TABLE 5-1 (Continued)

PHASE III RFI/RI
SOIL AND WASTE SAMPLING PARAMETERS

RADIONUCLIDES

- Gross Alpha
- Gross Beta
- Uranium 233+234, 235 and 238
- Americium 241
- Plutonium 239+240
- Tritium
- Strontium 90, 89
- Cesium 137

NOTE * Analytes for SWMUs 102 and 105 only.

5 2 NATURE AND EXTENT OF CONTAMINATION

In addition to source characterization, the Phase III RFI/RI will focus on additional ground-water, surface water, and sediment sampling to further characterize the nature and extent of contamination in each of these media arising from the IHSSs These sampling programs are outlined in detail below

5 2 1 Ground Water

5 2 1 1 Monitor Well Locations

Based on data collected during the Phase I and II investigations, volatile organics are present in the unconfined ground-water flow system at the 881 Hillside Area The extent of contamination is not fully delineated, and additional monitor wells are needed to define the vertical and lateral extent of the organics Potential major ion, trace metal, and radionuclide impacts to ground water were not well characterized in the Phase II RI report due to the lack of appropriate background ground-water quality data Presented below are proposed monitor well locations and rationale to further characterize ground-water flow and quality in the unconfined flow system within Operable Unit No 1 Bedrock wells will be installed adjacent to alluvial wells where sandstone is encountered

Upgradient Wells

Four new alluvial monitoring wells are proposed upgradient of the 881 Hillside Area to characterize the quality of ground water entering the sites These wells (MW20, MW21, MW22, and MW23) will all be completed in Rocky Flats Alluvium MW20 and MW21 will be located east and north, respectively, of Building 881, and wells MW22 and MW23 will be located on the Rocky Flats Alluvium terrace north of IHSSs 119 1 and 119 2 (Figure 5-1)

SWMUs 119.1 and 130

Three alluvial and three bedrock wells will be installed downgradient of IHSS 119 1 to further characterize the extent of volatile organics detected in wells 48-87, 10-74, 9-74, and 4-87 Alluvial well MW24 will be located between 9-74 and 4-87 and will be completed in colluvial gravel Data from this well will serve to further characterize the transport of contaminants found in wells 9-74 and 43-87 to well 4-87 Alluvial wells MW25 and MW26 will further delineate the extent of colluvial saturation and water quality south of IHSSs 119 1 and 130

Further investigation of the bedrock sandstone at well 5-87 is also proposed for the Phase III RFI/RI, because TDS, strontium, and selenium were elevated during 1989 Three wells (MW27, MW28, and MW29) are proposed for completion in this sandstone (Figure 5-1) As the extent and orientation of the sandstone and the ground-water flow direction within the sandstone are uncertain, these wells will be located in presumably upgradient (west), sidegradient (south), and downgradient (east) directions. Water level data from the wells will then be used to determine ground-water flow directions.

South Interceptor Ditch

In addition to well MW02, three other colluvial monitor wells will be installed along the South Interceptor Ditch These wells (MW30, MW31, and MW32) will serve to monitor ground-water quality and levels adjacent to the ditch (Figure 5-1), and the resulting data will be used to evaluate the interaction between South Interceptor Ditch surface water and unconfined ground water

Woman Creek Valley Fill Alluvium

Further characterization of valley fill water quality and the surface water/ground-water interaction are also needed along Woman Creek downgradient of the 881 Hillside Area Wells MW33, MW34, and MW35, in addition to well MW03, will all be completed in Woman Creek valley fill alluvium (Figure 5-1)

5 2 1 2 Chemical Analysis of Ground-Water Samples

Ground-water samples will be collected on a quarterly basis from all new and existing monitoring wells at the 881 Hillside Area upon completion of well development Samples will be analyzed for the parameters listed in Table 5-2 during the first round of sampling after completion of new wells This parameter list may be reduced in subsequent quarterly sampling events if certain parameter groups are not detected or are not significantly above background levels and if approved by EPA and CDH Ground-water samples will be analyzed in the field for pH, conductivity, and temperature Sample aliquots designated for metals, plutonium, americium and tritium analyses will be filtered in the field Samples will be preserved in the field and analyzed in the laboratory for the parameters listed in Table 5-2

5 2 1 3 Hydraulic Testing

In order to further characterize hydraulic conductivity values of geologic materials in the 881 Hillside Area, hydraulic tests will be performed in all newly installed monitor wells subsequent to well development These tests may be slug tests, bail down-recovery tests, or single hole pumping tests depending on the sustainable flow rate from a given well Hydraulic test data will be analyzed using a method appropriate to the field test method

Slug Tests	Bouwer and Rice (1976)
Bail-down/Recovery Tests	Theis (1935), Thiem (1906), or Cooper et al (1967)
Single Hole Pumping Tests	Theis (1935), Cooper and Jacob (1964)
Multi-Well Pumping Tests	Theis (1935), Cooper and Jacob (1964)
Tracer Injection Tests	Ogata (1970)

In addition, multi-well pumping and tracer tests will be performed along Woman Creek to further characterize the valley fill alluvium as discussed below Vertical hydraulic gradients will be determined from water level data

TABLE 5-2

PHASE III RFI/RI
GROUND-WATER SAMPLING PARAMETERS

FIELD PARAMETERS
- pH
- Specific Conductance
- Temperature

INDICATORS
- Total Dissolved Solids
- pH

DISSOLVED METALS
- Target Analyte List - Metals
  - Aluminum
  - Antimony
  - Arsenic
  - Barium
  - Beryllium
  - Cadmium
  - Calcium
  - Chromium
  - Cobalt
  - Copper
  - Iron
  - Lead
  - Magnesium
  - Manganese
  - Mercury
  - Nickel
  - Potassium
  - Selenium
  - Silver
  - Sodium
  - Thallium
  - Vanadium
  - Zinc
- Other Metals
  - Molybdenum
  - Strontium
  - Cesium
  - Lithium
  - Tin

ANIONS
- Carbonate
- Bicarbonate
- Chloride
- Sulfate
- Nitrate as N
- Cyanide
- Fluoride

ORGANICS
- Target Compound List - Volatiles
  - Chloromethane
  - Bromomethane
  - Vinyl Chloride
  - Chloroethane
  - Methylene Chloride
  - Acetone
  - Carbon Disulfide
  - 1,1-Dichloroethene
  - 1,1-Dichloroethane
  - total 1,2-Dichloroethene

TABLE 5-2 (Continued)

PHASE III RFI/RI
GROUND-WATER SAMPLING PARAMETERS

ORGANICS (CONT.)

Target Compound List - Volatiles (Continued)

- Chloroform
- 1,2-Dichloroethane
- 2-Butanone
- 1,1,1-Trichloroethane
- Carbon Tetrachloride
- Vinyl Acetate
- Bromodichloromethane
- 1,1,2,2-Tetrachloroethane
- 1,2-Dichloropropane
- trans-1,3-Dichloropropene
- Trichloroethene
- Dibromochloromethane
- 1,1,2-Trichloroethane
- Benzene
- cis-1,3-Dichloropropene
- Bromoform
- 2-Hexanone
- 4-Methyl-2-pentanone
- Tetrachloroethene
- Toluene
- Chlorobenzene
- Ethyl Benzene
- Styrene
- Total Xylenes

Target Compound List -- Semi-volatiles

- Phenol
- bis(2-Chloroethyl)ether
- 2-Chlorophenol
- 1,3-Dichlorobenzene
- 1,4-Dichlorobenzene
- Benzyl Alcohol
- 1,2-Dichlorobenzene
- 2-Methylphenol
- bis(2-Chloroisopropyl)ether
- 4-Methylphenol
- N-Nitroso-Dipropylamine
- Hexachloroethane
- Nitrobenzene
- Isophorone
- 2-Nitrophenol
- 2,4-Dimethylphenol
- Benzoic Acid
- bis(2-Chloroethoxy)methane
- 2,4-Dichlorophenol
- 1,2,4-Trichlorobenzene
- Naphthalene
- 4-Chloroaniline
- Hexachlorobutadiene
- 4-Chloro-3-methylphenol(para-chloro-meta-cresol)
- 2-Methylnaphthalene
- Hexachlorocyclopentadiene
- 2,4,6-Trichlorophenol
- 2,4,5-Trichlorophenol
- 2-Chloronaphthalene
- 2-Nitroaniline
- Dimethylphthalate
- Acenaphthylene
- 3-Nitroaniline
- Acenaphthene
- 2,4-Dinitrophenol

TABLE 5-2 (Continued)

PHASE III RFI/RI
GROUND-WATER SAMPLING PARAMETERS

ORGANICS (CONT.)

Target Compound List -- Semi-volatiles (Continued)

- 4-Nitrophenol
- Dibenzofuran
- 2,4-Dinitrotoluene
- 2,6-Dinitrotoluene
- Diethylphthalate
- 4-Chlorophenyl Phenyl ether
- Fluorene
- 4-Nitroaniline
- 4,6-Dinitro-2-methylphenol
- N-nitrosodiphenylamine
- 4-Bromophenyl Phenyl ether
- Hexachlorobenzene
- Pentachlorophenol
- Phenanthrene
- Anthracene
- Di-n-butylphthalate
- Fluoranthene
- Pyrene
- Butyl Benzylphthalate
- 3,3'-Dichlorobenzidine
- Benzo(a)anthracene
- bis(2-ethylhexyl)phthalate
- Chrysene
- Di-n-octyl Phthalate
- Benzo(b)fluoranthene
- Benzo(k)fluoranthene
- Benzo(a)pyrene
- Indeno(1,2,3-cd)pyrene
- Dibenz(a,h)anthracene
- Benzo(g,h,i)perylene

Target Compound List -- Pesticides/PCBs

- alpha-BHC
- beta-BHC
- delta-BHC
- gamma-BHC (Lindane)
- Heptachlor
- Aldrin
- Heptachlor Epoxide
- Endosulfan I
- Dieldrin
- 4,4'-DDE
- Endrin
- Endosulfan II
- 4,4'-DDD
- Endosulfan Sulfate
- 4,4'-DDT
- Endrin Ketone
- Methoxychlor
- alpha-Chlordane
- gamma-Chlordane
- Toxaphene
- AROCLOR-1016
- AROCLOR-1221
- AROCLOR-1232
- AROCLOR-1242
- AROCLOR-1248
- AROCLOR-1254
- AROCLOR-1260

TABLE 5-2 (Continued)

PHASE III RFI/RI
GROUND-WATER SAMPLING PARAMETERS

RADIONUCLIDES

- Gross Alpha (dissolved)
- Gross Beta (dissolved)
- Uranium 233+234, 235, and 238 (dissolved)
- Americium 241 (total)
- Plutonium 239+240 (total)
- Tritium (total)
- Cesium 137 (dissolved)
- Strontium 90 (dissolved)
- Radium 226, 228 (dissolved)

Pumping and Tracer Tests in Woman Creek Valley Alluvium

Pumping and tracer tests will be performed in the Woman Creek Alluvium to develop better estimates of solute travel times Currently, the hydraulic conductivity and effective porosity are known to estimated accuracies of about a factor of three, the dispersivity is known to an estimated accuracy of about an order of magnitude In order to measure these parameters in the field (especially the effective porosity) and to account for spatial variability, three pumping and tracer tests will be performed in the Woman Creek Alluvium between the 881 Hillside and Indiana Street The test locations are shown on Figure 5-2

Each test will be performed in an array of 15 wellpoints (Figure 5-3) The array has been designed to produce linear flow for the tracer test, however, the array is also suitable for the pumping test The wellpoints will consist of 1 5-inch diameter stainless steel wellpoints driven into the ground using a drill rig In order to minimize deviation from vertical while driving the wellpoints, a pilot boring will be made to approximately four feet below ground and the point driven through the hollow stem of the auger The screens will be five feet long so that the points are screened over the entire saturated thickness After completion of each test, the wellpoints will be pulled out of the ground and any remaining openings filled with neat cement grout with five percent bentonite The well points will be re-used in the next tests

Pumping Test

The pumping test will be performed by pumping Well A (Figure 5-3) at a constant rate for four hours In general, the Woman Creek alluvium varies in thickness from three to eight feet and the saturated thickness varies from about zero to four feet, although the alluvium can become fully saturated at times. The alluvium is a minimum of seventy-five feet wide and the hydraulic conductivity is approximately 1×10^{-3} cm/s, based on baildown-recovery and slug tests Preliminary calculations (assuming a saturated thickness of four feet, hydraulic conductivity of 1×10^{-3} cm/s, and a storage coefficient of 0 1) indicate that the Woman Creek alluvium can sustain a constant discharge of 0 17 gallons per minute (gpm) for the period of pumping with drawdowns ranging from two feet in a fully efficient pumping well to 0 19 feet at a distance of five feet

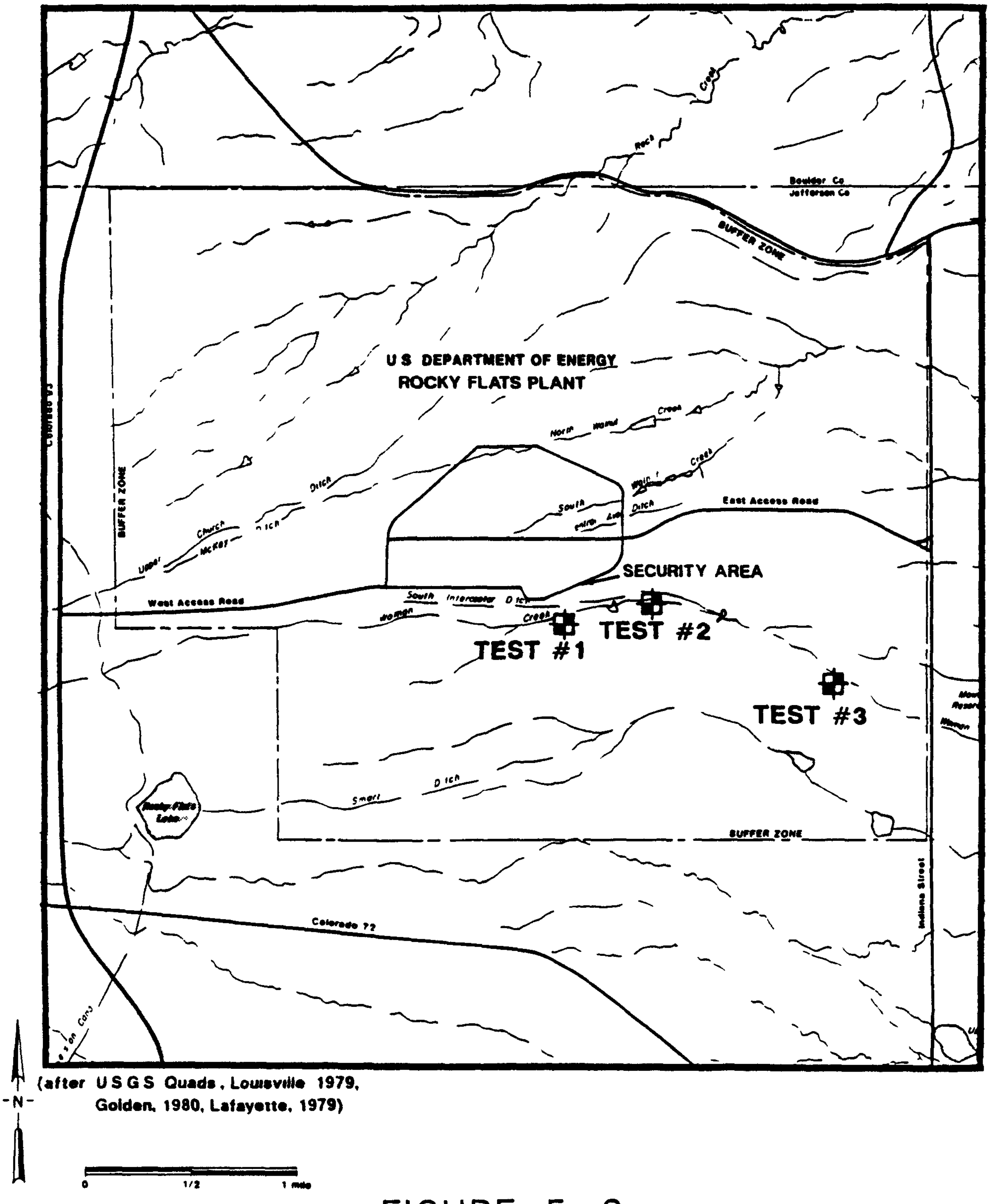

FIGURE 5-2
PUMPING AND TRACER TEST LOCATIONS

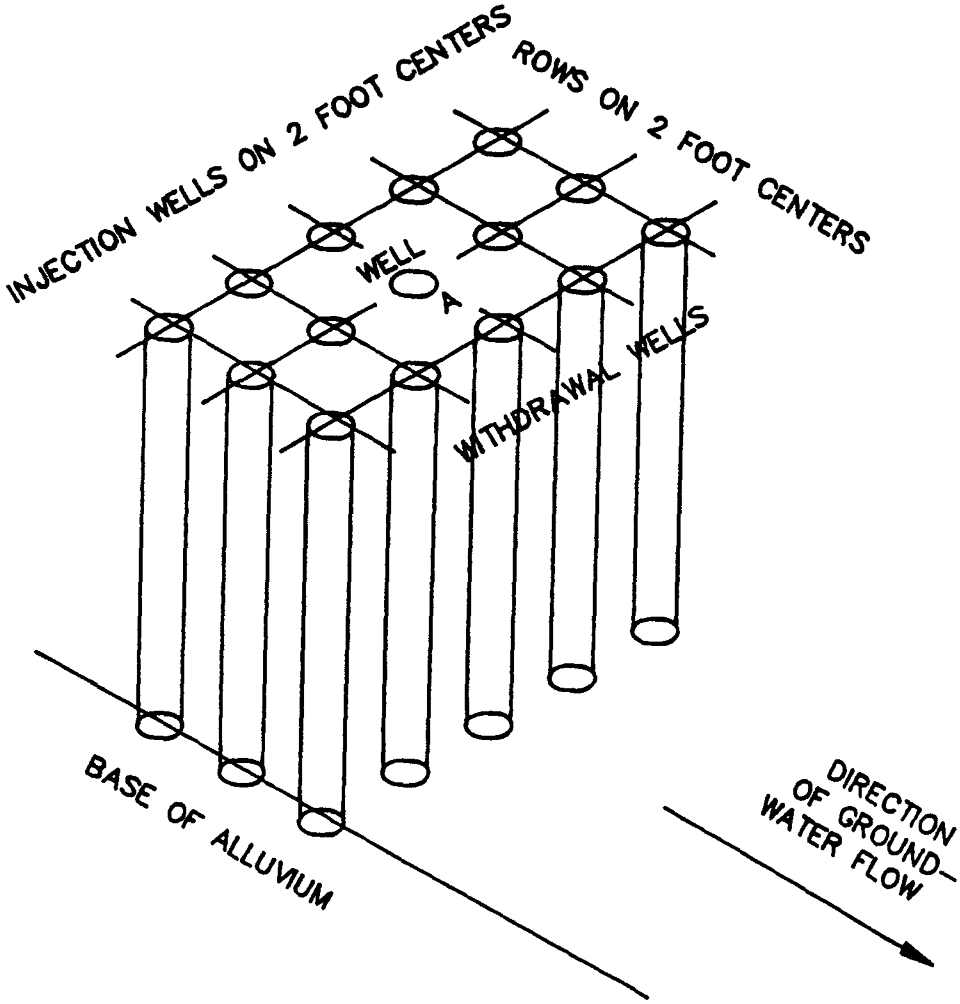

FIGURE 5-3
PUMPING AND TRACER TEST WELL ARRAY

The well will be suction-pumped using an electrically operated peristaltic pump A peristaltic pump is expected to perform well in this application because the suction lift is small (estimated to be no more than ten feet) and because a peristaltic pump can be run at very small, constant flow rates. All produced water will be drummed (41 gallons in four hours) and reinjected into the formation as part of the tracer test. Time-drawdown data during both the pumping and recovery periods will be collected from all of the wells using either depth to water probes or pressure transducers

The pumping test will be analyzed as a constant rate withdrawal test in unconfined materials to yield hydraulic conductivity and storage coefficient Delayed yield will be considered, if appropriate In addition, the efficiency of the well (theoretical drawdown divided by observed drawdown, times 100 percent) will be evaluated for use in the tracer test calculations

Tracer Test

A linear flow system will be created by injecting water into the five upstream wells and withdrawing water from the five downstream wells Although two lines of three wells can produce linear flow between the middle wells, two lines of five wells will be used in order to provide greater assurance of linear flow between the middle wells Water will be supplied to the injection wells and withdrawn from the withdrawal wells (Figure 5-3) using peristaltic pumps controlled by electrical liquid level probes Water levels in both the injection and withdrawal wells will be allowed to fluctuate approximately 0 20 feet and will result in an average head differential of one foot (gradient of 0 25) The water levels will be maintained such that the upstream wells produce a one foot head increase and the downstream wells produce approximately an unchanged head condition Heads in the formation will be calculated assuming that the well efficiencies are as determined in the pumping test

Steady linear flow will be created by injecting the ground water withdrawn during the pumping test plus waters withdrawn from the withdrawal wells It is estimated that each well will require an average steady flow of approximately 0 03 gpm (calculated using the Darcy equation) and that steady linear flow will be achieved in approximately seven hours

The tracer test will be performed in two phases after linear flow has been achieved The first phase will inject a non-conductive fluid (distilled water) into the injection wells, the arrival of the injection fluid at the downstream withdrawal wells will be indicated by a reduction of the conductivity of the water The natural conductivity of the alluvial ground water is approximately 500 to 1,000 micromhos per centimeter and that of distilled water is near zero

Although there are many other tracers that could be used in this test, distilled water is felt to be the least environmentally damaging and was therefore selected Releases of adsorbed ions from the solid phase to the distilled water may occur during the course of the test, however, the magnitude of this effect is expected to be small because of the quartzitic and granitic mineralogy of the formation If adsorbed ions are released, the steady state conductivity at the downstream wells will be somewhat higher than zero, the actual value will be used as the 100 percent concentration for breakthrough and earlier values scaled accordingly The impact of using a lower concentration tracer will be tested by re-injecting the produced formation fluids (higher conductivity) as a second phase of the test All water withdrawn during the test will be drummed for this later use If the lower conductivity water cannot be detected in the withdrawal wells, an alternate test will be designed using Rhodamine WT dye with either a fluorimeter or a spectrofluorometer for quantitative detection

Time-conductivity data will be collected from all of the wells using dedicated conductivity probes. Complete mixing of the water in the injection and withdrawal wells will be achieved with a recirculation system to avoid chemical stratification in the wellbore Conductivity will be measured in flow-through conductivity cells uphole Water will be added or withdrawn from the recirculation system on each well through solenoid valves controlled by the liquid level probes It is estimated that the 50 percent concentration will arrive at the withdrawal well approximately 400 minutes after injection begins (using an effective porosity of 0 1, hydraulic conductivity of 1×10^{-3} cm/s, gradient of 0 25 and a dispersivity of 0 1 feet) The test will continue until the conductivity in the middle withdrawal well stabilizes

During the second phase of the tracer test, the water collected during the first phase will be injected into the injection wells (approximately 150 gallons) without withdrawal from the withdrawal wells The intent of the second phase is to evaluate the impact of using a lower concentration tracer during the first phase The test will be performed as described above and the dispersivity recalculated for comparison with the original determination. During this phase, linear flow will be maintained but gradients may vary somewhat during the test because downstream withdrawal will not occur, possibly resulting in unsteady flow Again, the water in the withdrawal wells will be mixed using the recirculation system to prevent stratification in the wellbore. The test will continue until the conductivity of the water in the middle withdrawal well stabilizes

The time-conductivity data will be analyzed using the equation for dispersion in a semi-infinite medium in a unidirectional flow field (Ogata, 1970) The time at which the 50 percent concentration arrives at the downstream withdrawal well will be used to calculate the effective porosity (given that the gradient is known from the test conditions and the hydraulic conductivity is known from the pumping test) The dispersivity will be found by curve matching to the time-conductivity data

These calculations will yield a vertically averaged longitudinal dispersivity appropriate for use with a vertically averaged hydraulic conductivity The effects of hydraulic conductivity variations will be included in the calculated dispersivity It is recognized that spatial variation of both the hydraulic conductivity and the transport parameters is likely, therefore, three tests will be performed at different locations in the alluvium It is also recognized that dispersivity is a scale dependent parameter and that the dispersivity developed in these tests will only be appropriate for finely gridded analytical models (nodal spacings on the order of 4 to 40 feet) However, it is anticipated that the effective porosity values developed will be applicable for calculation of nondispersive ground-water flow velocities

A small test pattern was selected to cause measurable responses in a reasonable amount of time The 2-foot well spacing will permit measurable responses after four hours of pumping at 5 feet from the pumping well Each phase of the tracer test (establish linear flow, achieve 50 percent concentration, achieve 100 percent tracer concentration, repeat using natural salinity tracer to 50 percent concentration, achieve 100 percent natural salinity tracer concentration) is expected to require approximately seven hours Thus, the entire tracer test is expected to require approximately 35 hours for flow over only four feet of alluvium

Sediment stratification and artifacts of close well spacing and well development are potential sources of error for these aquifer tests. The test designs described above address these issues as follows

- Sediment stratification may play an important role in the hydraulic behavior of the system during the pumping and tracer tests. Calculations of system response in which thin, highly conductive layers are present will result in a slightly higher hydraulic conductivity and a considerably lower effective porosity However, these values will be appropriate for prediction of travel times in the layered system

- The ratio of the wellpoint spacing to the wellpoint diameter (2 feet divided by 1 5 inches, ratio of 16) is too great to achieve significant compaction between the wellpoints Department of the Navy (1983) predicts that an insignificant relative density can be achieved by driving piles at a spacing to diameter ratio of 16 This is consistent with field test reported by Basore and Boltano (1969) which resulted in no significant increased density for spacing to diameter ratios in excess of about 5

  Installation of wellpoints was selected as opposed to installation of monitor wells, to minimize disturbance of the alluvium for the purposes of these tests

- The degree of well development influences the response of the water level in the pumping well, but generally has little effect on the response of the observation wells The negligible impact of poor development on the response of observation wells results from the fact that head loss for flow through the well skin is proportional to the velocity squared Because very little water passes through the well skin (only that amount required to effect the water level change), the velocity is small and the head loss is even smaller Although significant removal of fines due to well development is not expected, the amount of development will be limited in order to minimize this effect. The degree of development will be evaluated as well efficiency (the ratio of actual drawdown to the theoretical drawdown)

5 2 2 Surface Water and Sediments

5 2 2 1 Sample Locations

Ten surface water stations were established south of the 881 Hillside Area in the Woman Creek drainage during the 1986 and 1987 investigations Surface water sampling at these stations is currently conducted on a monthly basis and will continue through 1990 Concurrent flow measurements will be made Figure 2-17 presents surface water monitoring locations in the area, and Table 5-3 presents the surface water stations to be sampled during the Phase III RFI/RI

TABLE 5-3

SURFACE WATER SAMPLING STATIONS

SW-31

SW-35

SW-44

SW-45

SW-46

SW-66

SW-67

SW-68

SW-69

SW-70

Bedload sediment samples were taken in October 1989 at stations along Woman Creek and the South Interceptor Ditch. The resulting data should suffice as confirmatory information regarding the concentrations of volatile organics, metals, other inorganics, and radionuclides in the sediments. However, sediment sampling is continuing at the Plant, and bedload sediment samples will be collected from the 881 Hillside Area For the Phase III RFI/RI, physical characteristics of the sediments (background and "downgradient") and the spatial distribution of the metal concentrations will be examined to assess the adequacy of the background sediment geochemical characterization and thus whether metals are contaminants in the sediments at the 881 Hillside Area Three new sediment stations will be established (SED-37, SED-38, and SED-39) near surface water sampling stations SW-35, SW-57, and SW-70, respectively These stations will presumably not be subject to influence by the 903 Pad Area as are the existing stations to the east.

5 2 2 2 Chemical Analysis of Surface Water and Sediment Samples

Laboratory analyses of surface water samples will consist of the parameters listed in Table 5-4, and sediments will be analyzed for the parameters listed in Table 5-1 Surface water samples will be analyzed in the field for pH, conductivity, temperature, and dissolved oxygen All samples requiring filtration will be filtered in the field, and all samples will be preserved in the field Surface water sampling and stream flow measurements will follow the procedures described in the Rocky Flats ER Program SOP (EG&G, 1990c)

5 2 3 Surficial Soils

Plutonium was elevated above background levels in Phase II RI boreholes from several sites in the 881 Hillside Area Plutonium contamination may be limited to the uppermost soil, for its suspected origin is windblown particulates from the 903 Pad Area In order to characterize the vertical and horizontal extent of surficial soil plutonium contamination, surficial soil scrapes and vertical soil profiles will be collected in remedial investigation areas, and in the Plant buffer zone south and east of these areas to Indiana Street during the 903 Pad, Mound, and East Trenches Areas (Operable Limit No 2) RI Surficial soil sampling planned for the Operable Unit No 2 Phase II RI also includes the 881 Hillside Area and is presented in the following section

TABLE 5-4

PHASE III RFI/RI
SURFACE WATER SAMPLING PARAMETERS

FIELD PARAMETERS
- pH
- Specific Conductance
- Temperature
- Dissolved Oxygen

INDICATORS
- Total Dissolved Solids
- Total Suspended Solids
- pH

DISSOLVED AND TOTAL METALS
- Target Analyte List - Metals
  - Aluminum
  - Antimony
  - Arsenic
  - Barium
  - Beryllium
  - Cadmium
  - Calcium
  - Chromium
  - Cobalt
  - Copper
  - Iron
  - Lead
  - Magnesium
  - Manganese
  - Mercury
  - Nickel
  - Potassium
  - Selenium
  - Silver
  - Sodium
  - Thallium
  - Vanadium
  - Zinc
- Other Metals
  - Molybdenum
  - Strontium
  - Cesium
  - Lithium
  - Tin

ANIONS
- Carbonate
- Bicarbonate
- Chloride
- Sulfate
- Nitrate as N
- Cyanide
- Fluoride
- Phosphate

ORGANICS
- Oil and Grease
- Target Compound List - Volatiles
  - Chloromethane
  - Bromomethane
  - Vinyl Chloride
  - Chloroethane
  - Methylene Chloride
  - Acetone

TABLE 5-4 (Continued)

PHASE III RFI/RI
SURFACE WATER SAMPLING PARAMETERS

ORGANICS (CONT.)

- Target Compound List - Volatiles (Continued)
  - Carbon Disulfide
  - 1,1-Dichloroethene
  - 1,1-Dichloroethane
  - total 1,2-Dichloroethene
  - Chloroform
  - 1,2-Dichloroethane
  - 2-Butanone
  - 1,1,1-Trichloroethane
  - Carbon Tetrachloride
  - Vinyl Acetate
  - Bromodichloromethane
  - 1,1,2,2-Tetrachloroethane
  - 1,2-Dichloropropane
  - trans-1,3-Dichloropropene
  - Trichloroethene
  - Dibromochloromethane
  - 1,1,2 Trichloroethane
  - Benzene
  - cis-1,3-Dichloropropene
  - Bromoform
  - 2-Hexanone
  - 4-Methyl-2-pentanone
  - Tetrachloroethene
  - Toluene
  - Chlorobenzene
  - Ethyl Benzene
  - Styrene
  - Total Xylenes

DISSOLVED AND TOTAL RADIONUCLIDES

- Gross Alpha
- Gross Beta
- Uranium 233+ 234, 235, and 238
- Americium 241
- Plutonium 239+240
- Tritium
- Cesium 137
- Radium 226, 228
- Strontium 90

In order to assess the extent of plutonium in surficial soils within Plant boundaries, collection of soil samples has been planned as part of the Phase II RI/FS at Operable Unit No 2 (EG&G, 1990g) Figure 5-4 was constructed by including all areas where soil plutonium concentrations were expected to exceed two dpm/g (approximately one pCi/g) This area consists of approximately 800 acres The State of Colorado requires special techniques for construction on lands with plutonium concentrations greater than two dpm/g of dry soil To evaluate the soil plutonium values relative to this standard, the CDH sampling protocol will be used

Phase I sampling at the 881 Hillside showed that some soils outside that zone contained more than one pCi/g of plutonium, so the soil sampling area has been expanded (Figure 5-4) The CDH sampling protocol will be used for sampling on the 10 acre grid It requires that 25 subsamples be composited within a 10-acre area to compose a soil sample Grids will not be contiguous except near the 903 Pad Area Lines of grids will be placed to define the southern and northern extent of contamination Other grids will be used to confirm values from within the areas of concern The northwest corner of each grid will be located by survey and identified with an appropriately marked steel post. Grids will be oriented on the cardinal compass directions. The 25 subsamples will be located with a handheld compass and tape measure using the northwest corner as the starting point

In order to assess the vertical distribution of plutonium 239 + 240 an americium 241 in the soil profile, subsurface sampling will also be done at the locations shown on Figure 5-4 One subsurface soil sampling location will be placed at the center of each of the 24 10-acre plots to facilitate comparison of the data Backhoe pits will be excavated at each of the indicated locations to a depth of one meter A 1/8 inch surface scrape, 1/8 inch to 1 cm deep sample, and 1 cm to 5 cm deep sample will be taken Samples will then be collected each 5 to 10 cm Samples will be collected from the face of the pit, with all samples being collected within 50 cm of each other horizontally The samples will be collected from the bottom upward to the surface and equipment will be decontaminated between collection of each sample

5.3 EVALUATION OF PROPOSED INTERIM REMEDIAL ACTION

An interim remedial action is proposed at the 881 Hillside Area to collect, treat, and discharge the treated alluvial ground water Alluvial ground water will be collected by a french drain across the hillside and pumped to a water treatment plant at the top of the hillside A geotechnical and geochemical soils investigation was recently performed at the 881 Hillside Area in order to evaluate the site characteristics along the proposed french drain alignment, a potential french drain extension, and associated influent and effluent lines (Figure 5-5). Results of the investigation will be evaluated prior to the Phase III RFI/RI field activities.

5 3 1 Borehole Locations

A series of 42 borings on approximately 100 foot centers were drilled along the entire length of the influent/effluent lines, the french drain alignment, and the potential french drain extension The following information was obtained from these borings

- Geotechnical soil and bedrock samples and testing (in situ and laboratory) to assist in the design of the french drain system and evaluate the slope stability of the 881 Hillside,
- Accurate lithologic logs and depth to bedrock,
- Geologic data for generating geologic cross sections
- Samples for chemical analyses that add to the 881 Hillside database, determine health and safety requirements for construction activities, and determine disposal requirements for excavated soils

Thirty-two of these boreholes were drilled along the proposed french drain alignment and potential french drain extension The objectives of these boreholes are to determine

- Geotechnical characteristics of the bedrock and surficial materials,
- Accurate lithologic logs, including depth to bedrock and location of subcropping bedrock sandstone units,
- Hydraulic conductivities of each five foot depth interval in bedrock and discrete conductivities of any subcropping sandstones that are encountered,

- Chemical characteristics of soils along the alignment to determine
    - a. Appropriateness of proposed french drain location,
    - b Appropriate level of health and safety protection for french drain construction, and
    - c Appropriate disposition of excavated soils.

Four of the 32 french drain alignment boreholes were completed as piezometers (Figure 5-5) These piezometers will serve to characterize the extent of saturation downgradient of IHSS 119 2 which will evaluate the need for extending the french drain to include this area.

Six of the 32 boreholes along the french drain alignment were not located on 100 foot centers (not shown on Figure 5-5) These were drilled to collect representative colluvial geotechnical samples and/or to perform additional packer testing where borehole collapse occurred The geotechnical sampling was necessary because there was inadequate soil left over after collecting samples for geochemical analysis from the boreholes on 100 foot centers.

Ten boreholes were drilled along the proposed influent/effluent pipeline alignment. Select samples from these boreholes were submitted for laboratory geotechnical analyses of area soils (Section 5 3 3), and one set of samples from each borehole were submitted for geochemical analysis General objectives of these influent/effluent boreholes are to determine

- Geotechnical characteristics of area soils.
- Accurate lithologic logs and depth to bedrock
- Chemical characteristic of soils to determine
    - a Appropriate level of health and safety protection for construction, and
    - b Appropriate disposition of excavated soils

In addition, four piezometers will be installed at one location along the french drain during the Phase III RFI/RI to assess the effectiveness of the drain (Figure 5-1) PZ01 will be completed in weathered claystone adjacent to wells MW24 (colluvium completion) and MW25 (weathered sandstone completion) Together, these wells and piezometers will serve to characterize the extent of saturation in various geologic units upgradient of the french drain Piezometers PZ02, PZ03, and PZ04 will be completed in colluvium, weathered claystone, and weathered sandstone (if present), respectively, to characterize the extent of saturation downgradient of the french drain Water levels in these wells and piezometers will be monitored both prior and subsequent to construction of the french drain in order to observe changes caused by its operation

5 3 2 Chemical Analysis of Soil Samples

Boreholes along the proposed french drain alignment were continuously sampled for lithologic descriptions from ground surface to bedrock Discrete soil samples were collected for volatile organic analysis every two feet, and composite samples for metal, inorganic, semi-volatile organic, pesticide, PCB, and radionuclide analyses were collected every four feet, when recovery permitted Soil samples were analyzed for the parameters listed in Table 5-1

One set of samples from each of the influent/effluent boreholes were submitted for the analytes listed in Table 5-1 A continuous sample was obtained from zero to five feet in depth A discrete soil sample from five feet was submitted for volatile organic analysis using stainless steel sleeves inserted directly into the core barrel before drilling, and the remaining material was homogenized and submitted for the other analytes The anticipated depth of the influent/effluent pipeline is four to five feet This sampling and analysis scheme will enable the health and safety protocol for pipeline construction to be established, and will determine the ultimate disposal option for excavated soil

5 3 3 Geotechnical Testing of Soil Samples

Geotechnical soil samples along the proposed french drain alignment were obtained from boreholes in accordance with standard penetration test procedures (ASTM D-1586) Fourteen samples were submitted to the laboratory for geotechnical testing Geotechnical tests include moisture content, density, Atterberg limits, and grain size distribution to further characterize geologic materials at the 881 Hillside In order to evaluate slope stability, direct shear tests were conducted on eight soil samples

Boreholes along the proposed influent/effluent pipeline alignment were drilled from ground surface to the top of bedrock Soil samples were collected every five feet in accordance with standard penetration test procedures (ASTM D-1586) Twenty-one soil samples were collected from these boreholes and were submitted to the laboratory for geotechnical testing Physical analyses included moisture content, density and grain size distribution, and confined compressive strength tests. Additionally, ten unconfined compressive strength tests were conducted on select samples to help evaluate slope stability

5 3 4 Geotechnical Testing of Bedrock Samples

Approximately 18 feet of bedrock were cored in each of the proposed french drain alignment borings, and geotechnical tests were conducted on selected sections of core These tests included saturated back pressure permeability (constant head), direct shear strength, unconsolidated undrained triaxial shear, strength, unconfined compressive strength, moisture and density and grain size analysis Sandstone units were not observed during the french drain geotechnical investigation drilling and were therefore not packer tested

5 3 5 In Situ Packer Testing

In situ packer tests were performed in boreholes drilled along the proposed french drain alignment to further characterize the hydraulic conductivity of weathered bedrock at the 881 Hillside Area The tests were conducted in cored sections of open bedrock boreholes to isolate and test the hydraulic conductivity at depths of five, ten, and fifteen feet below the alluvium/bedrock contact. The detailed procedures for performing packer tests and for analyzing results are described in the ER Program SOP (EG&G, 1990c)

SECTION 6

ENVIRONMENTAL EVALUATION PLAN

6 1 INTRODUCTION

The objective of this Environmental Evaluation Plan is to provide a framework for addressing nsks to the environment from potential exposure to contaminants resulting from the 881 Hillside Area. This plan is prepared in conformance with the requirements of current applicable legislation, including CERCLA, as amended by SARA, and follows the guidance for such studies as provided in the NCP and EPA documents for the conduct of RCRA Facility Investigation activities Specifically, the EPA guidance provided in "Risk Assessment Guidance for Superfund, Vol II, Environmental Evaluation Manual" (U S EPA, 1989d) is followed

The goal of the environmental evaluation is to determine the nature and extent of potential impacts of contamination from Operable Unit No 1 to plants and animals (biota) Determination of the effects on biota will be performed in conjunction with the human health risk assessment for the 881 Hillside Where appropriate, criteria necessary for performing the environmental evaluation will be developed in accordance with human health risk assessments and environmental evaluations for all Rocky Flats Plant operable units Determination of ecological impacts will be limited to those contaminants whose effects on biota are adequately documented in the scientific literature Information from the environmental evaluation will assist in determining the form, feasibility, and extent of remediation necessary for the 881 Hillside Area in accordance with CERCLA.

6 1 1 Approach

This plan presents a three-stage, sequential approach for conducting the environmental evaluation at the 881 Hillside This phased and comprehensive approach is designed to ensure that all procedures to be performed are appropriate, necessary, and sufficient to adequately characterize the nature and extent of environmental effects to biota under the "no action" scenario As is recommended by EPA, this environmental evaluation is not intended to be or to develop into a research-oriented project The plan presented herein is designed to provide a focused investigation of potential contaminant effects on biota Each stage of the environmental evaluation activities will be coordinated with sitewide RFI/RI activities in order to avoid unnecessary duplication of effort and resources

Stage I of the environmental evaluation will focus on planning, review and integration of available data, and conduct of ecological field investigation Data quality objectives (DQOs) will be defined, and procedures for monitoring and controlling data quality will be specified Preliminary field surveys and an ecological inventory will be conducted in Stage I to characterize the 881 Hillside study area biota and note the locations of obvious zones of chemical contamination and ecological effects. Site history, chemical data, results from the RFI/RI fate and transport models, and existing ecological data will be reviewed and evaluated Stage I activities will include a preliminary assessment of population-, community-, or ecosystem-level impacts (endpoints) to be measured Stage I activities will provide a preliminary determination of the contaminants of concern and their potential adverse effects to key receptor species at the 881 Hillside, and will allow a conceptual ecological model of the site to be prepared

Stage II will entail development of a conceptual pathways model based on the ecological field investigation and inventory This exposure-receptor pathways model will be used to evaluate the transport of contaminants from the 881 Hillside source to biological receptors The conceptual pathways model prepared in Stage II will provide an initial determination of the movement and distribution of contaminants, likely interactions among ecosystem components, and expected ecological effects

Scoping and design of the Stage III investigation will be determined by the outcome of the preliminary Stage II analyses and pathways model During Stage III, tissues will be analyzed from selected species to document current levels of specific target analytes The primary endpoint for Stage III is the detection of chemicals of concern in target species Selection of the target analytes, species, and tissues will be based on the Stage II determination of which contaminants are likely to be present in sufficient concentrations, quantities, and locations as to be detected in biota The need for measuring additional endpoints in Stage III through reproductive success, enzyme inhibition, or other toxicological-type studies will be evaluated based on results from Stage I and Stage II analyses as well as appropriate acceptance criteria

6 1 2 881 Hillside Contamination

Contamination of soil, ground water, surface water, and sediment occurs in the 881 Hillside Area, although the exact extent is difficult to assess, given uncertainties in much of the data. Also, many possible contaminants have been found only infrequently and/or just above background levels, or may be associated with laboratory contamination From the data available, it appears that the major constituents (organics, metals, and radionuclides) present above background levels are the following

Soil

Organics PCE, TCE, 1,1,1-TCA, methylene chloride, acetone and phthalates,

Metals cadmium, arsenic, antimony, mercury, manganese and barium, and

Radionuclides plutonium, americium, uranium, cesium and tritium.

Ground Water

Organics PCE, TCE, 1,1-DCE, 1,1-DCA, 1,1,1-TCA, 1,1,2-TCA, CCl_4, toluene, 1,2-DCA, $CHCl_3$, acetone, methylene chloride, ethyl benzene, carbon disulfide, 2-butanone, vinyl acetate, total 1,2-DCE, total xylenes, and benzene,

Inorganics nitrate, chloride, sulfate, TDS, magnesium, sodium, calcium, potassium, and cyanide,

Metals nickel, strontium, zinc, manganese, mercury, copper, selenium, lithium, barium, beryllium, iron, antimony, chromium, lead, aluminum, cadmium, cobalt and molybdenum, and

Radionuclides uranium, tritium, strontium 89, 90, americium, radium 226 and cesium 137

Surface Water

Organics PCE, toluene, CCl_4, methylene chloride, acetone and 2-butanone,

Inorganics TDS, nitrate, sulfate, magnesium, calcium and potassium,

Metals strontium, zinc, aluminum, barium, iron, beryllium, cadmium, copper, mercury, lead, chromium, selenium, vanadium and nickel, and

Radionuclides uranium, plutonium, strontium 89, 90, amencium, cesium 137, tritium, radium 226

Sediments

Organics chloromethane, TCE, chloroform, acetone, methylene chlonde, carbon disulfide, 2-butanone and toluene,

Inorganics nitrate, magnesium and potassium,

Metals beryllium, silver, tin, possibly aluminum, antimony, cadmium, chromium, copper, iron, lead, lithium, magnesium, manganese, mercury, selenium, strontium, thallium, vanadium, zinc and molybdenum, and

Radionuclides plutonium, uranium and radium 226

Many of the metal contaminants are likely to impact biota at Operable Unit No 1 if present at sufficient concentrations Several of the metal contaminants found in the 881 Hillside Area can be taken up by plants through their roots or deposited on plant leaves and stems In addition, they can be inhaled and ingested by animals These metals have various effects on biological organisms When ingested, antimony, arsenic, beryllium, cadmium, chromium, lead, mercury, selenium and tin can be toxic Arsenic, cadmium, lead and mercury function as cumulative poisons, while beryllium, chromium, nickel and arsenic are carcinogenic Cadmium and lead cause neurological disruption, and copper, mercury, tin, cobalt and nickel act as biocides to certain species at low concentrations Some trace metals such as arsenic are thought to be essential trace metals in mammalian species

Many of the metal contaminants biomagnify with increasing trophic levels In terrestrial habitats, this occurs from soil to plants for beryllium, cadmium, lead, mercury, nickel, selenium, tin and vanadium In herbivores, an increase occurs for antimony, arsenic, cadmium, chromium, copper, lead, mercury and selenium Only mercury and cadmium biomagnify in terrestrial carnivores In aquatic habitats, biomagnification has been found in algae for antimony, arsenic, cadmium, copper, chromium, cobalt, lead, mercury, nickel, selenium, tin and vanadium In aquatic herbivores, an increase occurs for antimony, arsenic, cadmium and mercury, in carnivores, an increase occurs for cadmium and mercury

Bioaccumulation occurs within an organism when the organism stores specific contaminants Arsenic, cadmium, chromium, cobalt, copper, lead, mercury, nickel, selenium, tin and vanadium are concentrated by a number of biological organisms potentially present in the 881 Hillside environment

Several of the volatile organic compounds found at 881 Hillside, such as PCE, are on the EPA Priority Toxic Pollutants List and are known to have acute and chronic toxic effects on aquatic life depending on their concentrations The elevated levels found in ground-water samples warrant evaluation for their potential exposure to receptor organisms

High nitrate levels were found in the ground water, surface water and sediments Nitrates are relatively nontoxic to organisms although they can cause eutrophication problems Under reduced oxygen conditions, nitrites and ammonia are especially toxic to aquatic organisms

According to the Radioecology and Airborne Pathway Summary Report (Rockwell International, 1986f), plutonium is not considered to pose an ecological hazard to biota unless extremely high levels [>1 microCurie per square meter (mCi/m^2)] occur The reason for this is thought to be the extremely low biological mobility of the common forms of the element. These findings and other studies on the ecological effects of radionuclides will be reviewed for their applicability to the 881 Hillside environmental evaluation

6 1 3 Protected Wildlife, Vegetation and Habitats

6 1 3 1 Wildlife

The U S Fish & Wildlife Service has identified several listed endangered or threatened wildlife species which could possibly occur in the Rocky Flats Plant area However, none is expected to occur because of lack of habitat These species include the bald eagle (endangered), peregrine falcon (threatened), whooping crane (endangered) and black-footed ferret (endangered)

The bald eagle (Haliaeetus leucocephalus) is primarily a winter resident around rivers and lakes, and the closest known nesting pairs are found at Barr Lake, 25 miles to the east of Rocky Flats The whooping crane (Grus americana) passes through Colorado during its spring and fall migrations Whooping cranes, blown off their migration course, could use the Rocky Flats area as a night roost These birds prefer large marshes and wetlands in broad open river bottoms and prairies Such habitat is not present at Rocky Flats

Two subspecies of peregrine falcon (Falco peregrinus tundris and F p. anatum) may occasionally occur in the Rocky Flats area as they hunt for prey Nesting preferences are high cliff sides and river gorges, both of which are absent at Rocky Flats However, nesting sites have been recorded to the west about 4 to 5 miles from the site.

The historical geographic range of the black-footed ferret (Mustela nigripes) coincides with that of the prairie dog, a principal prey species However, the black-footed ferret populations are now much reduced but still are associated with some prairie dog towns Large prairie dog towns (>80 acres for black-tailed prairie dogs) sufficient to support a black-footed ferret population are not expected to be present at Rocky Flats

6 1 3 2 Vegetation

Ten federally-listed or proposed plant species occur in Colorado, all of which are western slope species None of these is known or expected to occur on or near Rocky Flats A number of candidate species for federal listing are known to occur in Jefferson and Boulder Counties but have not been identified at Rocky Flats

6 1 3 3 Wetlands

Numerous regulations and acts have been promulgated to protect water-related resources, including wetlands Wetlands play an important role in ecosystem processing and in providing habitat to a variety of plant and animal species An assessment of Rocky Flats wetlands was completed in 1989 (EG&G, 1990h), these wetlands currently fall under the jurisdiction of the Corps of Engineers Wetlands occur along Woman Creek and Pond C-2, and DOE activities with a potential to impact wetlands must follow regulations designed for their protection

6 1 4 Scope of Work

In order to accomplish the plan objectives, a number of activities will be prepared and executed These are briefly described below

Stage I

- Project Preparation - This activity includes project planning, identification of DQOs, and final design of the ecological inventory field sampling plan Also included is the review and analysis of existing information, identification of data gaps, and a preliminary determination of the contaminants of concern and their documented ecological effects on key receptor species

- Ecological Field Investigation - This activity represents the field surveys, inventory and food habit studies necessary to characterize the biota at the 881 Hillside Area Brief field surveys will be conducted in the winter, spring, summer and fall in the study area to obtain information on the occurrence, distribution, variability and general abundance of key plant and animal species A field inventory will be conducted in late spring to obtain quantitative data on the ecological attributes of important species' populations Samples collected as part of the activity will be saved wherever possible for use in the Stage III tissue analyses As part of these activities, all collected field data will be reduced, evaluated, compared with and integrated into the existing data bank and food web model to update knowledge of site conditions

Stage II

- Contamination Assessment - This activity includes the toxicity assessment, exposure assessment, development of the conceptual pathways model and characterization of impacts to biota posed by exposures to 881 Hillside contaminants

Stage III

- Biological Contamination Studies - This activity includes field and laboratory analyses of contaminant levels in select plant and/or animal species. This activity may include additional toxicological-type investigations such as reproductive success or enzyme inhibition studies Samples collected in Stage I will be used wherever possible, new samples will be collected if needed

- Remediation Criteria - Statutes require the selection of remedial actions sufficient to protect the environment This activity entails consideration of federal and Colorado laws and regulations pertaining to preservation and protection of natural resources that are ARARs. Available data on chemical exposures and toxicities will be evaluated and, to the extent practicable, criteria will be established that address biological resource protection

- Environmental Evaluation Report - This activity represents the preparation of the report which addresses the scope of the investigation, site environmental characteristics and contaminants, characterization of effects, remediation criteria, conclusions and limitations of the assessment

Elements of the scope of work are described in the following sections Stage I preliminary planning is presented in Section 6 2 The Stage I field investigation is described in Section 6 3 Section 6 4 presents the Stage II contamination assessment Section 6 5 describes the Stage III contamination studies Remediation criteria are discussed in Section 6 6 A suggested outline for the environmental evaluation report is presented in Section 6 7 The field sampling plan presented in Section 6 8 includes both the Stage I ecological investigation and the Stage III contamination studies

6 2 PROJECT PREPARATION (STAGE I)

An environmental evaluation of the 881 Hillside Area is necessary for Rocky Flats Plant to meet the requirements of Sections 121(b)(1) and (d) of CERCLA An environmental evaluation, in conjunction with the human health risk assessment, is required to ensure that remedial actions are protective of human health and the environment Guidelines for conducting this evaluation, which is also called an ecological assessment, are provided by EPA in Risk Assessment Guidance for Superfund, Volume II, Environmental Evaluation Manual (U S EPA, 1989d) Additional guidance is derived from EPA's Ecological Assessments of Hazardous Waste Sites A Reference Document (U S EPA, 1989c)

The environmental evaluation is both a qualitative and quantitative appraisal of the actual or potential injury to plants and animals (biota) other than humans and domesticated species due to contamination at the 881 Hillside The environmental evaluation is intended to reduce the inevitable uncertainty associated with understanding the environmental effects of contaminants present at the 881 Hillside and to give more definitive boundaries to that uncertainty during remediation

The plan for implementation of the 881 Hillside environmental evaluation provides a framework for the review of existing data, the conduct of subsequent field investigations, and the preparation of the contamination assessment. The staged approach presented in this plan begins with the activities described in the following section preliminary planning, DQO development, support documentation, and review of existing information The field investigation and inventory, which is also part of Stage I, is described in Section 6 3

6 2 1 Preliminary Planning

This task includes an initial determination of the scope of the environmental evaluation, identification of DQOs, and a plan for determining the types of information required for each stage of the environmental evaluation Types of information required in Stage I of the evaluation include the following

- Species present at 881 Hillside, community structure and food webs,
- Obvious signs of ecological impacts,
- Contaminant inventory,
- Contaminant sources and locations, chemical and radionuclide analyses of soil and water;
- Sediment composition and quality, grain sizes and total organic carbon, and
- Toxicity data to provide a preliminary determination of potential effects of contaminated media on receptor species

As an integral part of the RFI/RI process, Stage I of the environmental evaluation will focus on accumulating and analyzing pertinent information on three major areas

- Species, populations and foodweb interrelationships,
- Presence, distribution and concentrations of contaminants in the abiotic environment (e g , soil, surface water, ground water and air), and
- Potential exposure pathways and the effects of contaminants on various biological components in the affected ecosystems This is the conceptual pathways model

Data from past studies and preliminary data from current environmental studies will be used to better define the present distribution of contaminants in the abiotic environment. Based on this information, a food web model will be developed to provide a preliminary identification of potential exposure pathways or combinations of pathways and receptor species at risk

Information that will be developed from Stage I of the environmental evaluation includes the following

- Criteria for selection of contaminants of concern, key receptor species and reference areas These criteria will be applicable to environmental evaluations at all operable units
- Species inventory - Plant and animal species known to occur within Operable Unit No 1 or to potentially contact contaminants at Operable Unit No 1
- Population characteristics - General information on the abundance of key species
- Food habit studies - Available information from literature sources to supplement field observations on key species
- Field surveys - Inventory of 881 Hillside biota and locations of obvious zones of chemical contamination and ecological effects
- Chemical inventory - Existing information including that obtained on chemical contaminants from other investigations at Rocky Flats and other DOE facilities will be used in the development of a preliminary list of contaminants of concern

This information will provide the basis for the Stage II contamination assessment (Section 6 4) In the contamination assessment, comprehensive food webs and contaminant exposure pathways will be developed for 881 Hillside Information on these food webs will be related to quantitative data on contaminants in the abiotic environment. These data will then be used to evaluate potential impacts to biota due to exposure from the contaminants

Field studies for contamination will be conducted in Stage III for both aquatic and terrestrial systems Information from the Stage I field survey and the Stage II contamination assessment will determine the methods to be used Tissue analyses will be conducted on selected species from 881 Hillside and reference areas to document current levels of specific target analytes Selection of the target analytes, species and tissues will be based on the Stage II determination of which contaminants are likely to be present in sufficient concentrations, quantities and locations at the 881 Hillside Area as to be detected in biota.

The need for measuring additional endpoints in Stage III through reproductive success or other identified endpoints will be evaluated based on the Stage II pathway analysis. Toxicity-based methods may involve the measurement of a biological effect associated with exposure to complex mixtures For this method, the selection of toxicological endpoints for indicator or target species will be based on a review of available scientific literature providing quantitative data for the species of concern Another approach involves the analysis of population, habitat or ecosystem changes Analysis of population, habitat or ecosystem changes will be based on species or habitats that represent broad components of the ecosystem or are especially sensitive to the contaminants Selection of the methodology will be based on appropriate acceptance criteria, e g

- Measurement endpoint corresponds to or is predictive of the assessment endpoint,
- Methodology is capable of demonstrating a measurable biological response distinguishable from other environmental factors such as weather or physical site disturbance,
- Measurement is practical to perform and produces scientifically valid results,
- Methodology and measurement endpoint are appropriate to the exposure pathway, and
- A standard acceptable protocol exists for the methodology

Determination of impacts will be based on establishment of a statistically significant difference in the biological response between samples from populations at the 881 Hillside and at the reference area The determination as to what constitutes a statistically significant difference will be consistent with DQOs and quality assurance provisions of the QAPjP

6 2 2 Data Quality Objectives

The DQO development process will be initiated during State I preliminary planning Development of DQOs will follow the three steps recommended by EPA. Step I of the DQO process involves preparing definitions and concise DQOs Examples of Step I program DQOs for this environmental evaluation include the following

- Identify appropriate site-specific receptor species and contaminants of concern to determine if there is a potential for adverse impacts to occur as a result of potential contaminant release,

- Evaluate the potential for impacts to occur to biological resources outside the boundaries of the 881 Hillside Area or Rocky Flats Plant, and

- Evaluate the need for remediation to protect the environment.

Steps II and III of the DQO process include identification of data uses and needs and design of the data collection program Products of Step II include proposed statements of the type and quality of environmental data required to support the DQOs, along with other technical constraints on the data collection program. The objective of Step III is to develop data collection plans that will meet the criteria and constraints established in Steps I and II Step III results in the specification of methods by which data of acceptable quality and quantity will be obtained The DQO development process will continue as scoping of the environmental evaluation becomes more refined Additional Step I decision-type DQOs may be needed or data collection-type DQOs may be modified based on results of the Stage I preliminary planning process and subsequent refinement of the field sampling plan

6 2 3 Support Documentation

In addition to the work plan, proper conduct of this environmental evaluation will be dependent upon development of a field sampling plan The purpose of the field sampling plan is to ensure that field data collection activities will be comparable to and compatible with previous data collection activities performed at the site while providing a mechanism for planning and approving new field activities The field sampling plan provides guidance for all fieldwork by defining in detail the sampling and data-gathering methods to be used on the project. The preliminary field sampling plan for this environmental evaluation is presented in Section 6 8

Guidance for the selection and definition of field methods, sampling procedures and custody was acquired from the Compendium of Superfund Field Operations Methods, which is a compilation of demonstrated field techniques that have been used during remedial response activities at hazardous waste sites (U S EPA, 1987b, hereafter referred to as the Compendium) To the extent possible, procedures from the Compendium are incorporated by reference

6 2 4 Review of Existing Information

As an essential part of the environmental evaluation at the 881 Hillside Area, a review of documents, aerial photographs, and data relevant to the site will be completed This will allow compilation of a data base from which to determine data gaps and to provide evidence for a defensible field sampling program If available and applicable, historical data will be used

During preparation of this work plan, several documents were reviewed as part of an assessment of available information These included the Final EIS, Rocky Flats Plant (U S DOE, 1980), Wetlands Assessment (EG&G, 1990h), Draft RI Report for the High Priority Sites 881 Hillside Area (Rockwell International, 1987a, 1988a), Final Environmental Assessment for 881 Hillside (U S DOE, 1990c), among others Literature reviews will continue during the environmental evaluation Review of all available data formed the basis for the establishment of the initial sampling locations discussed in the Section 6 8

6 3 FIELD INVESTIGATION (STAGE I)

The following field investigation consists of three separate programs The air program will entail emissions estimation and modeling The soils, surface water and ground-water program will be conducted as part of the Phase III RFI/RI activities The terrestrial and aquatic biota sampling program will be conducted as part of this environmental evaluation

6 3 1 Air Quality

It is necessary to model ambient air concentrations to estimate environmental risk which results from airborne transport of 881 Hillside contaminants to potential receptors Emission estimates will be calculated for surface wind erosion and for the diffusion of volatiles and semivolatiles existing below the surface through the top layer of soil Wind erosion emissions will be estimated for total particulates, metals and radionuclides while soil diffusion emissions will be estimated for volatiles and semivolatiles detected below the surface, as determined from ground-water, surface soil and soil boring sampling results Air quality dispersion modeling using a Chi/Q approach, which assumes a unit emission rate, will be performed Compound-specific emission rates will then be multiplied by the modeled impacts to produce compound-specific ambient concentration estimates, since predicted concentrations are directly proportional to the emission rate

Based on the dispersion modeling results, 24-hour and annual compound-specific ambient concentrations will be estimated at a set of receptor points on and downwind of the actual 881 Hillside Area Pathways will then be defined using these receptors and risks calculated as necessary These estimates of ambient concentrations will then be used to perform a baseline risk assessment for each chemical of concern detected above background levels in the soil and ground water

6 3 2 Soils

Site-specific soil data on contaminants present in surficial deposits currently exist for the 881 Hillside Area These data were collected as part of Phases I and II of the RFI/RI for the 881 Hillside Drilling was conducted to identify and characterize past waste disposal sites Boreholes were drilled within and adjacent to the IHSSs, and soil samples were collected and analyzed for organics, inorganics, metals and radionuclides Sequences of Rocky Flats Alluvium, colluvium, recent valley fill and Arapahoe Formation were sampled and tested in the field and laboratory Geologic and hydrologic data from Phases I and II drilling programs provided the basic framework for defining a chemical/hydrologic/geologic model for the 881 Hillside Source contaminants and concentrations, as well as possible flow paths, rates and accumulations, were preliminarily assessed to characterize the dynamic system

Volatile organics data for soils previously collected from the 881 Hillside Area were rejected during the data validation process and cannot be used in a quantitative sense Analytical results of the Phase III soil samples will be reviewed and interpreted for use in this environmental evaluation

The Phase III RFI/RI Work Plan proposes an additional soil sampling program at 881 Hillside to further characterize the extent of contamination, gain additional hydrologic data and resolve questions regarding the presence and concentration of volatile organics Under the program, boreholes will be drilled to provide continuous core of the Rocky Flats Alluvium, colluvium, recent valley fill and the Arapahoe Formation Soil samples will be analyzed for organics, inorganics, metals and radionuclides

As in prior programs, the soil sampling locations will be placed in areas to characterize specific sites Sample density as proposed in Section 5 is considered sufficient to provide a clear picture of soil characteristics and contaminant concentrations for all soil types found in the 881 Hillside area The substances to be tested are also considered sufficient for the environmental evaluation

Soil analysis results are related to surface and ground-water regimens Fluids moving through the soils can act to leach contaminants, transport them through available flow paths and deposit them in downgradient environments. Soil analyses may help define extent of contaminant sources as well as areas of accumulation

Near-surface soil scrapings (top 1 cm) will be of prime importance for determining source contaminants for biota This uppermost layer is a major source of nutrient and contaminant uptake for the vegetation under study and is a potential source of contaminant ingestion to wildlife Sampling and analysis programs under Phase III RFI/RI field investigations will be reviewed and modified when necessary to ensure that sampling intervals and methods are appropriate to collect surficial soil samples

6 3 3 Surface Water

Phase I and II surface water sampling and analytical results were evaluated with respect to this environmental evaluation plan Sampling locations presented in the work plan (Figure 2-18) are continuing to be sampled on a monthly basis through 1990 as part of the overall Plant sampling program All seeps and springs on the 881 Hillside will be sampled as part of this ongoing program Chemical results from the surface sampling locations will be reviewed and incorporated into the environmental evaluation

6 3 4 Ground Water

Results of the Phase I and II ground-water investigations along with planned Phase III activities for 881 Hillside were reviewed for incorporation in the preparation of this environmental evaluation Data from the Phase III program will aid in characterizing the nature and areal extent of ground-water contamination at the 881 Hillside The hydrogeologic information and laboratory analytical results from the planned Phase III boring and well installation program will likewise be used in the environmental evaluation The above information will be used to assess the nature and extent of contamination in shallow ground water and help identify exposure pathways for the environmental assessment

6 3 5 Terrestrial and Aquatic Biota

Few site-specific biological data exist for the 881 Hillside Area. Field surveys will be conducted to characterize biological site conditions in terms of species presence, habitat characteristics and/or community organization The emphasis will be to describe the structure of the biological communities at the 881 Hillside in order to identify potential pathways, biotic receptors and key species

6 3 5 1 Vegetation

The objectives of the vegetation sampling program are to provide data for (1) description of site vegetation characteristics, (2) identification of potential exposure pathways from contaminant releases to higher trophic-level receptors, (3) selection of key species for contaminant analysis to determine background conditions for the 881 Hillside, and (4) identification of any protected vegetation species or habitats The selection of key species is a subjective decision based on species dominance or judged importance in the food chain Criteria will be determined for the selection of key species

Terrestrial Vegetation

Vegetation is sparse and characteristic of disturbed areas except on the eastern edge of the 881 Hillside Grasses characteristic of the short grass plains are abundant Representative species include Junegrass (Koeleria cristata), Dropseed (Sporobolus spp), slender wheatgrass (Agropyron trachycaulum) and green needlegrass (Stipa viridula), which are interspersed with other grasses, shrubs, and a variety of annual flowering plants Transects will be established on 881 Hillside and along the Woman Creek drainage to collect phytosociological data on density, cover, frequency, biomass and species presence

Wetland Vegetation

Wetlands have been identified along Woman Creek (EG&G, 1990h) These occur as linear wetlands which support hydrophytic vegetation species including sandbar willow (Salix exigua), american watercress (Barbarea orthoceras), and plains cottonwood (Populus sargentii) Other species associated with these wetlands include broad-leaf cattail (Typha latifolia), baltic rush (Juncus articus), cordgrass (Spartina pectinata), silver sedge (Carex praegracilis) and various bulrushes (Scirpus spp.)

Aquatic Vegetation

The periphyton community is a closely-adhering group of organisms that form mat-like communities on rocks and other solid objects on the stream bottom It is composed of algae, bacteria, fungi, detritus and other macroscopic heterotrophic organisms Because of the large surface-to-volume ratio of its constituents, periphyton have been found to be an excellent indicator community for accumulation of contaminants Periphyton samples will be collected at designated locations on Woman Creek and Pond C-2

Periphyton communities provide a sensitive mechanism to detect changes in aquatic environments that result from the introduction of contaminants Taxonomic composition and relative abundance of periphyton can be measured on natural substrates as well as standardized artificial substrates On hard artificial substrates, data on algal abundance, biomass and species composition can be obtained by removing the substrate and by scraping or brushing the flora from a measured area into a container

6 3 5 2 Wildlife

A field survey will be conducted to gather data on animal communities at the 881 Hillside The objective of the animal life survey is to (1) describe the existing animal community; (2) identify potential contaminant pathways through trophic levels, (3) develop food web models including contribution from vegetation, (4) identify key species for potential collection and tissue analysis, and (5) identify any protected species

Terrestrial Species

Songbirds, larger mammals, reptiles and raptors may use the area daily, seasonally or sporadically, or wander through as vagrants. The field survey will document the presence of terrestrial species and allow for a general description of the community

Aquatic Species

Benthic macroinvertebrates probably exist as soft bottom communities in Woman Creek and Pond C-2 The soft-bottom benthos is defined as those macroscopic invertebrates inhabiting mud or silt substrates. Because these communities are essentially stationary, they are good integrators of past and present habitat contamination Additionally, their feeding methods (filtering microscopic organisms and fine materials and grazing periphyton), suggest that benthic species are incorporating other organisms that are potentially concentrating contaminants Designated locations in Woman Creek and Pond C-2 will be sampled for benthic organisms

6 3 6 Reference Areas

Reference areas will be selected when current and historical data are not available to assess impacts from 881 Hillside contaminants One or more reference areas will be selected based upon their similarity to the 881 Hillside Area and their lack of exposure to contamination Data collected at the reference area will be compared where possible to values reported in the scientific literature to demonstrate that the data represent a normal range of conditions Methods used to collect data at the reference area will be comparable to those used at the 881 Hillside Area

Reference areas will be identified for terrestrial, wetland and aquatic species to the west or north of the Plant away from potential effects associated with releases from either Rocky Flats Plant or the 881 Hillside Sampling rationale, methodologies and procedures for both terrestrial and aquatic sampling are presented in Section 6 8, the Field Sampling Plan

The selection of reference areas will meet Step I DQOs and the selected assessment and measurement endpoints Criteria for the selection of reference areas will be developed during Stage I preliminary planning

Two basic criteria will be employed in the selection and establishment of reference areas

1 The reference areas will be similar to the 881 Hillside Area in terms of soil series, topography, aspect, vegetation and habitat types and plant and animal assemblages.

2 The reference areas, including vegetation and wildlife, have not been impacted by releases from the 881 Hillside Area or other Rocky Flats Plant operable units.

6 4 CONTAMINATION ASSESSMENT (STAGE II)

The two major objectives of the contamination assessment are to

- Obtain quantitative information on the types, concentrations, and distribution of contaminants in selected species, and
- Evaluate the effects of contamination in the abiotic environment on ecological systems

Conducting a contamination assessment requires an evaluation of chemical and radiological exposures and the subsequent toxicological effects on key species. Of specific importance in the contamination assessment are the identification of exposure points, the measurement of contaminant concentrations at those points and the determination of potential impacts or injury Impacts may result from movement of contaminants through ecological systems or from direct exposure (inhalation, ingestion, deposition)

The Stage II Contamination Assessment for 881 Hillside will be based on existing environmental criteria, published toxicological literature and existing, site-specific environmental evaluations The program design will be integrated with other ongoing RFI/RI studies so that concentrations of contaminants in abiotic media can be related to contaminant levels and effects in biota

The contamination assessment process is divided into the following five tasks

- Site characterization,
- Contaminant identification,
- Toxicity assessment,
- Exposure assessment, and
- Impact Evaluation

The objectives and description of work for each of these tasks is described below

6 4 1 Site Characterization

Environmental resources at the site will be characterized based on data reviews from existing literature and reports, including results from the Phase III RFI/RI investigation and the environmental evaluation field studies The description of the site will be presented in terms of the following distinct resource areas

- Meteorology/Air Quality;
- Soils and Geology,
- Surface and Ground Water Hydrology,
- Terrestrial Ecology,
- Aquatic Ecology, and
- Protected/Important Species and Habitats

The purpose of the site characterization is to describe resource conditions as they exist without remediation The narrative with supporting data will include descriptions of each resource, with attendant tables and figures, as appropriate, to depict, in a concise and clear fashion, site conditions, particularly as they influence contaminant fate and transport.

6 4 2 Contaminant Identification

Because there is a variety of individual contaminants associated with the 881 Hillside Area, it is critical to narrow the list of chemicals to a manageable number Chemical and species-specific criteria will be used for selecting those contaminants which are of particular concern from an ecological perspective at the 881 Hillside Although the selection process will parallel that for the human health risk assessment, the lists will differ somewhat based on contaminant fate and transport characteristics and species-specific toxicities Selection of the contaminants of concern will be evaluated in accordance with EPA guidance

6 4 3 Exposure Assessment

This task will identify the exposure or migration pathways of the contaminants, taking into account environmental fate and transport through both physical and biological means Each pathway will be described in terms of the chemical(s) and media involved and the potential ecological receptors The exposure assessment process will include the following four subtasks

- Identify exposure pathways,
- Identify key receptor species,
- Determine exposure points and concentrations, and
- Estimate chemical intake for receptors

Each of these subtasks is described below

6 4 3 1 Exposure Pathways

The purpose of this subtask is to qualitatively identify the actual or potential pathways by which various biological receptors at or near the 881 Hillside might be exposed to site-related chemicals or radionuclides The exposure pathway analysis will address the following four elements

- A chemical/radionuclide source and mechanism of release to the environment,
- An environmental transport medium (soil, water, air) for the released chemical/radionuclide,
- A point of potential biological contact with the contaminated medium, and
- A biological uptake mechanism at the point of exposure

All four elements must be present for an exposure pathway to be complete and for exposure to occur

Exposure pathways will be evaluated and modeled, where possible, in this Stage II contamination assessment Toxicity tests may eventually be used based on model results or the need to conduct a direct effects-related investigation

6 4 3 2 Identification of Key Receptor Species

Key receptor species are those species which are or may be sensitive to the particular contaminants of concern Species that need to be considered in the contamination assessment include threatened and protected species, game species and species at higher trophic levels in food webs where contaminants are expected to bioaccumulate

Criteria for the selection of key receptor species will be based on a preliminary analysis of exposure routes and food web relationships as well as the known toxicological effects of the contaminants of concern This analysis will include an evaluation of the species in relation to potential contaminant exposure through both direct contaminant accumulation from the abiotic environment and bioaccumulation through the food chain

Key receptor species may be the mule deer (Odocoileus hemionus) which is mobile and has a large home range, or an organism which is sedentary or has a more restricted movement such as plants, some invertebrates, and some small vertebrates For contaminants that bioaccumulate, the effects are usually most severe for organisms at the top of the food chain (e g , top predators) Examination of contaminant effects on these more mobile species may necessitate the integration of data from different operable units

6 4 3 3 Determination of Exposure Points and Concentrations

The identified exposure points are those locations where key ecological receptor species may contact the contaminants of concern Determination of exposure points entails an analysis of key receptor species, locations and food habits in relation to potential contaminant exposure through both direct contaminant accumulation or deposition from the abiotic environment and through indirect bioaccumulation

A discussion of the nature and extent of contamination in the abiotic media (air, soils, surface water, and ground water) is presented in Section 2 of this Phase III RFI/RI Work Plan Phase III data will be summarized and used to characterize source areas and release characteristics at the site The exact exposure points can be expected to vary depending on both the contaminant and the key receptor species under consideration

Concentrations of chemicals that are likely to have the greatest impact (based on concentration in the environment, toxicity values, and biological uptake) will be determined by environmental fate and transport modeling or actual environmental media sampling for each exposure point Fate, transport and endpoint contamination levels will be modeled using environmental multi-media risk assessment models Such models can provide the potential maximum concentrations of chemicals at the exposure points by which to evaluate the "worst-case" scenario

6 4 3 4 Estimation of Chemical Intake by Key Receptor Species

This step includes an evaluation of key receptor species' contaminant uptake by direct routes (inhalation, ingestion, dermal contact) and indirect routes (bioaccumulation) The amounts of chemical and radiological uptake will be estimated in the Stage II contamination assessment using appropriate conservative assumptions, site-specific analytical data, and guidance from EPA's Exposure Factors Handbook Direct measurement of contaminant uptake through tissue analyses will be conducted during Stage III of the environmental evaluation

6 4 4 Toxicity Assessment

This assessment will include a summary of the types of adverse effects on biota associated with exposure to site-related chemicals, relationships between magnitude of exposures and adverse effects, and related uncertainties for contaminant toxicity, particularly with respect to wildlife Ecological receptor health effects will be characterized using EPA-derived critical toxicity values when available in addition to selected literature pertaining to site- and receptor-specific parameters.

Tissue contaminant analyses will be performed on samples of key species in Stage III These measurement endpoints will be chosen based on the predicted concentrations and the known toxicological effects of single contaminants on receptor species The species, contaminants and tissues to be sampled will be evaluated during Stage I preliminary planning

Toxicity tests may be performed to address the biological effects associated with exposure to complex mixtures The need for toxicity testing will be evaluated during Stages I and II of the environmental evaluation.

6 4 5 Impact Evaluation

Impact evaluation entails the integration of exposure concentrations and reasonable worst-case assumptions with the information developed during the exposure and toxicity assessments to characterize the current and potential impacts to the environment posed by contamination of the 881 Hillside Area The potential impacts from all exposure routes (inhalation, ingestion and dermal contact) and all media (air, soil, ground water and surface water/sediment) will be included in the impact evaluation as appropriate

Characterization of ecological impacts on receptor species is generally more qualitative in nature than characterizing human risks This is because the toxicological effects of most chemicals have not been well documented for most species Where specific information is available in the published literature, a more quantitative evaluation of effects will be made This approach is in agreement with EPA guidance documents (U S EPA, 1989d)

6 4 5 1 Ecological Effects Criteria

Criteria that are usable and applicable for the evaluation of ecological effects are generally limited EPA Ambient Water Quality Criteria (AWQC) and Maximum Allowable Tissue Concentrations (MATC) are the most readily available criteria Criteria found in federal and Colorado state laws and regulations pertaining to the preservation and protection of natural resources can also be used Criteria may also be derived from information developed for use under other environmental statutes, such as the Toxic Substances Control Act or the Federal Insecticide, Fungicide and Rodenticide Act

General information on the toxicity and environmental behavior of chemical contaminants in relation to biological resources will be compiled The selection of ecological effects criteria will be based on available data which document the adverse effects of each potential contaminant of concern Selection of these criteria will be coordinated with other RFI/RI studies and environmental evaluations.

6 4 5 2 Uncertainty Analysis

The process of assessing ecological effects is one of estimation under conditions of uncertainty To address these uncertainties, the environmental evaluation for the 881 Hillside Area will present each conclusion, along with the issues that support and fail to support the conclusion, and the uncertainty accompanying the conclusion Factors that limit or prevent development of definitive conclusions will also be discussed In summarizing the assessment data, the following sources of uncertainty and limitations will be specified

- Variance estimates for all statistics,
- Assumptions and the range of conditions underlying use of statistics and models, and
- Narrative explanations of other sources of potential error

6 5 CONTAMINATION STUDIES (STAGE III)

Stage III will include the tissue analysis studies and any additional toxicity studies used to determine impacts from the contaminants of concern on receptor species An initial design for the Stage III program will be completed in Stage I, after contaminants of concern and key receptor species have been selected Species to be sampled for tissue analyses will be designated to the extent possible prior to implementation of the Stage I field inventory in order to avoid a duplication of sampling effort.

In order to demonstrate an impact, the biological response under consideration and the proposed methodology should satisfy program DQOs as well as the following more specific criteria

- The biological response is a well-defined, easily identifiable and a documented response to the contaminant,
- Exposure to the contaminant is known to cause the biological response in laboratory experiments or experiments with free-ranging organisms,
- The biological response can be measured using a published standardized laboratory or field testing methodology;
- The biological response measurement is practical to perform and produces scientifically valid results, and
- The determination of impact will be based on the establishment of a statistically significant difference in the biological response between samples from populations in the reference area and the 881 Hillside Area.

6 5 1 Tissue Analysis

Tissue analyses will be conducted to measure the total concentration of specific chemical compounds in key receptor species Because individuals and species accumulate contaminants differentially in their tissues, environmental concentrations and general uptake rates will not necessarily predict biotic concentrations or adverse effects Analysis of tissue contaminant concentrations will provide data to evaluate the relationship, if any, between environmental concentrations and the amount of contaminants accumulated in receptor species Selection of the species and specific tissues for analysis will be based on a preliminary evaluation of site-specific food webs and potential contaminant transport pathways

To the extent possible, tissue samples will be collected simultaneously with environmental media samples This will allow for a determination of site-specific bioconcentration factors (BCFs) These BCFs will be incorporated into the final exposure assessment and pathways analysis model Where BCFs cannot be determined, published or predicted BCF values will be used in the pathways model to assess potential impacts

Prior to conducting the State III tissue analysis studies, the field sampling plan will be refined and more specific DQOs will be formulated The field sampling plan will address the following

- The number and types of analyses to be run,

- The species, locations, and tissues to be sampled,
- The number of samples to be taken,
- The detection limits for contaminants, and
- The acceptable margin of error in analyzing results

6 5 2 Toxicity Tests

Toxicity tests may include either in-situ (in-field) or laboratory toxicity tests In-situ methods usually involve exposing animals in the field to existing aquatic or soil conditions. Laboratory toxicity tests can be used to evaluate the lethal or sublethal effects of chemicals as they occur in environmental media. Both approaches can be used to test for toxicity of mixtures as they actually occur in the environment. Selection of a particular methodology will be based on the capability of the method to demonstrate a measurable biological response to the selected contaminant(s) of concern

6 6 REMEDIATION CRITERIA

Remediation criteria protective of site-specific plants and animals for the contaminants of concern can be developed based on detailed food web analyses These ecological effects criteria are determined by tracing the biomagnification of contaminant residues from organisms at the top of the food web back through intermediate trophic levels to the abiotic environment. The "no effects" criteria levels for abiotic media are then derived from contaminant concentrations known to produce effects in the highest trophic level organisms

The acceptable (no effects) criteria levels will be used in conjunction with ARARs to evaluate potential adverse effects on biota as is appropriate for the environmental evaluation portion of the Phase III RFI/RI This approach will be integrated with the human health risk assessment process and will assist in the development of potential remediation criteria

6.7 ENVIRONMENTAL EVALUATION REPORT

An Environmental Evaluation Report will be prepared in a clear and concise manner to present study results and interpretation All relevant data from the environmental evaluation, in addition to relevant Phase III RFI/RI data, will be integrated and evaluated in the characterization of potential environmental impacts The following topics will be covered in the report

- Objectives,
- Scope of Investigation,
- Site Description,
- Contaminants of Concern and Key Receptor Species,
- Contaminant Sources and Releases,
- Exposure Characterization,
- Impact Characterization,
- Remediation Criteria, and
- Conclusions and Limitations

A proposed, detailed outline of the report is shown in Table 6-1

6 8 PRELIMINARY FIELD SAMPLING PLAN

The environmental evaluation of the 881 Hillside Area is planned in three stages as described in Section 6 1 5 Field sampling activities will be conducted in Stage I and Stage III of the environmental evaluation Stage I will include brief field surveys and an ecological inventory of biota present at Operable Unit No 1 The field surveys will be conducted to obtain information on the occurrence, distribution and general abundance of 881 Hillside biota. Data obtained in the field inventory will be used to develop a detailed food web model of Operable Unit No 1 and to provide input to the Stage II pathways analysis Planning for the Stage III tissue analysis program will begin in Stage

TABLE 6-1

DRAFT ENVIRONMENTAL EVALUATION REPORT OUTLINE
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I, so that samples collected in the Stage I field inventory may be used for Stage III tissue analysis wherever possible The need for further contaminant studies (e g , reproductive success or enzyme analyses) in Stage III, in addition to the tissue analyses, will be determined based on Stage I and Stage II findings

The following field sampling plan is provisional and may be modified The Stage I sampling plan is largely complete but may be altered in order to better coordinate with the surface water and soil sampling programs. The Stage III field sampling plan will be designed in greater detail after contaminants of concern and key receptor species have been identified and a preliminary determination of food webs and contaminant source-receptor pathways has been developed This information will allow determination of which contaminants of concern are likely to be present in sufficient concentrations to be detected in biota and which biota are most practical and suitable for sampling

6 8 1 Sampling Objectives

The Stage I sampling program for 881 Hillside has four broad objectives

1 Conduct brief field surveys and an ecological inventory to describe the existing ecological setting in terms of habitats, vegetation, wildlife and aquatic species Observations for obvious signs or zones of contamination or impacts to biota and their habitats will be made The inventory will be accomplished through the use of established ecological field methodologies

2 From the above data, identify key food chain species which represent the major flow of energy and thus the major pathways for contaminant transfer from physical environmental media to higher trophic-level ecological receptors.

3 Identify the presence or absence of protected or other important species and habitats.

4 Provide site-specific information for determining objectives, measurement endpoints and methodologies for any needed Stage III field/laboratory contamination studies

Data from the Stage I field surveys and inventory will be summarized, tabulated and accompanied with a narrative description of the following data types

- Species Present,
- Habitat Descriptions,
- Critical/Protected Habitats,

- Protected Species,
- Terrestrial and Aquatic Foodwebs,
- Potential Exposure Pathways,
- Abundance of Key Species,
- Vegetation Biomass,
- Vegetation Cover;
- Vegetation Frequency and Density (shrubs/trees), and
- Vegetation Importance (community dominance) Values.

Appropriate statistical tests will be used to analyze the data so that precision and accuracy of the results can be presented at a stated level of confidence Depending on the data types being analyzed, within-and-between station differences, within-and-between season differences, and within-and-between species differences will be presented Means, variances, standard errors, analyses of variance, regression and correlation coefficients will be computed as appropriate Non-parametric methods will be employed where variances are heteroscedastic and population distribution is non-normal Where sample sizes are insufficient to detect differences, only descriptive statistics will be prepared

6 8 2 Sample Location and Frequency

Both Stage I and Stage III field sampling activities will be located and timed to the extent possible to coincide with collection of other media samples such as soils, surface water and ground water This will provide a synoptic view of potential contaminants in all relevant media at one time

The field sampling plan for Stage I is based on the assumption that brief field surveys will be conducted in the winter, spring, summer and fall of 1991 and that the ecological field inventory will take place within the May-June 1991 timeframe Information from the surveys and initial field inventory will be used to evaluate the need for a mid- to late-summer inventory A second inventory period would be required if field data indicated a summer-to-fall pulse of key species' populations important to the environmental evaluation

6 8 2 1 Locations for Vegetative Sampling

Stage I vegetation inventory and sampling for phytosociological data will be performed at Operable Unit No 1, along the South Interceptor Ditch and Woman Creek south and east of the 881 Hillside Area A systematic walk-through of these areas will be conducted during the field surveys and spring field inventory

A stratified randomization procedure will be utilized to identify sampling locations for the quantitative vegetative description portion of the field inventory The basis for selecting a random procedure of vegetation transect/plot location is to obtain as unbiased an estimator as possible of true population parameters for cover, density and frequency Stratification is required because several distinct vegetation types appear to be present in the study area, including prairie grassland, marsh, streambank vegetation, well-vegetated disturbed areas and sparsely vegetated disturbed areas.

The basis for stratification will be a vegetation type map, to be prepared based on the 1975 University of Colorado vegetation map of Rocky Flats, updated by visual observations during the field surveys This map will cover the 881 Hillside Area and the nearby areas along Woman Creek and the South Interceptor Ditch

Vegetable sample plots will be located near soil sampling sites whenever possible The exact location of the study plots will be selected by a double randomization procedure The first, used to select the soil sample locations, is described in Section 5 2 3 of this RFI/RI Work Plan From each soil sampling point, the centerpoint of a vegetation plot will be selected based on a random distance (to 10 m) and random direction, using random numbers tables Plot locations will be selected until an adequate number has been selected for each major vegetation type Locations will be discarded under several conditions where the selected location is in a vegetation type for which an adequate number of plots has already been selected, where the vegetation of the plot is not homogeneous (located in more than one type, or across an ecotone), and where the plot would be located in buildings or paved areas A similar process will be used for transects along Woman Creek and the South Interceptor Ditch, where the sample locations will be in the general area of the soil, sediment or water sampling points Since vegetation types associated with these features tend to be linear, the randomization process may require limits on direction In addition, multiple plots will be located near [within 50 meters (m) of] each water sampling point to provide an adequate sample size

6 8 2 2 Locations for Periphyton Sampling

Periphyton samples will be collected at the following surface water sampling locations SW-31, SW-32, SW-46, SW-70 and Pond C-2 (Figure 2-18) Should periphyton be absent at a particular location, the nearest location downstream supporting periphyton will be sampled and located on a map

6 8 2 3 Locations for Wildlife Sampling

A terrestrial wildlife inventory will be conducted within the 881 Hillside Area, the South Interceptor Ditch and along Woman Creek south and east of 881 Hillside Small mammal sampling will be conducted, to the extent possible, at the vegetative sampling locations

Benthic organisms and fish will be collected at SW-31, SW-32, SW-46, SW-70 and Pond C-2 If no aquatic habitat is present at these designated locations, the nearest downstream location with suitable habitat will be sampled The intent is to sample for benthos and fish at locations that also are sampled for sediments and surface waters.

6 8 2 4 Stage III Tissue Sampling Locations

Locations for the collection of Stage III tissue samples (terrestrial vegetation, periphyton, benthos, macrobenthos, fish) will be based on surface water, soil and sediment sample locations, as well as potential contaminant release areas Stage III sampling locations will include Stage I sampling sites (i e five x,y coordinate blocks), designated locations near or within IHSSs 102, 107, 130, 119 1 and 119 2 and 130, and surface water sampling locations SW-31, SW-32, SW-46, SW-70 and Pond C-2 Depending on the analysis and selection of contaminants of concern, contaminant sources, key receptor species, contaminant pathways and exposure points, the above sampling locations may change The intent is to collect tissue samples where existing abiotic media sampling occurs, to the extent possible

6 8 2 5 Sample Frequency

Stage I field surveys will be conducted during one-week periods in the winter, spring, summer, and fall of 1991 Special note of transitory species, migratory species, and seasonal breeding habits will be made during these multi-season surveys

Stage I field inventory sampling will occur during May/June 1991 Where possible, samples collected during the inventory will be saved and used in the Stage III tissue analysis studies.

6 8 3 Reference Areas

Stage III tissue analysis studies will require the sampling of contaminated and control areas in order to establish a relationship between contaminated conditions and background conditions in areas not exposed to Rocky Flats Plant contamination Selection of reference areas will be based on criteria developed in the Stage I preliminary planning process. Potential selection criteria include the presence of species to be sampled and similarity to the 881 Hillside in terms of topography, aspect, soils, vegetation, range type and land use history Reference areas will be upwind from prevailing air flow patterns through and upstream of drainage off the Plant.

The aquatic species reference areas ideally should be located in Rock Creek A site visit will be made to the proposed aquatic sampling locations (existing surface water sampling points SW-31, SW-32, SW-46, SW-70, Pond C-2) at the 881 Hillside Area (Figure 2-18) Habitat characteristics will be noted if not previously recorded in on-going Plant studies (depth, flow, substrate type, pool/riffle, aquatic/streamside vegetation, etc) This process will be repeated at potential reference sites The reference site locations will be based on DQOs and the measurement endpoints selected in the Stage I and Stage III sampling plans

6 8 4 Stage I - Field Survey and Inventory Sampling Methods

6 8 4 1 Vegetation

Both qualitative and quantitative methods will be used to characterize the terrestrial and wetland vegetation at the 881 Hillside The following qualitative procedure will be used in the Stage I field surveys

1 Systematically walk the 881 Hillside Area, the South Interceptor Ditch and Woman Creek area

2 Record on a vegetation data sheet all vegetation species encountered Information to be recorded includes

- Scientific name,
- Common name,
- Life form,
- Vegetative stage at the time,
- Qualitative statement on condition, and
- Qualitative statement on abundance

The following quantitative procedures will be used in the Stage I field inventory to collect structural and compositional data

- At each plot selected by the process described in Section 8 2 1, a 10 m long transect will be laid out in the randomly-selected direction
- All shrubs will be enumerated which are rooted within 1 m of the transect centerline Shrubs are defined as woody vegetation over 0 5 m in height, and with a stem diameter of less than 2 5 cm at 1 4 m aboveground, smaller woody plants will be counted within the herbaceous stratum, and larger ones as trees For each shrub rooted within the belt transect, the following data will be recorded species, height, and two cover diameters at right angles (to calculate areal average)
- Herbaceous cover will be visually estimated by species to the nearest percent within a 1 m^2 plot
- Biomass (dry weight) of herbaceous and low shrub vegetation will be obtained by clipping from a ¼ m^2 plot.
- Trunk diameter, height, canopy diameter, and species of each tree within 5 m of the transect centerline will be recorded
- Field data will be processed to yield mean cover, density (shrubs and trees), diameter (trees), biomass, and frequency by species and/or life form Each plot/transect will be considered as

an observation in calculating the mean and variance Sample adequacy will be determined for herbaceous cover and biomass (fresh weight) using Cochran's formula (1977)

$$N = \frac{(t^2)(s^2)}{[(x)(d)]^2}$$

where
- N = the minimum number of samples needed
- t = t distribution value for a given level of confidence
- s^2 = the variance estimate
- x = the mean of the sample
- d = the level of accuracy desired

Since adequate sample size may differ for cover sampling than for biomass sampling, different sample sizes may be required In addition, sample sizes may differ among vegetation types

6 8 4 2 Terrestrial Wildlife and Invertebrates

The Stage I survey will note the presence or absence of terrestrial/wetland species and their food habits The survey procedure will include a systematic walk-through of the 881 Hillside Area, South Interceptor Ditch and Woman Creek to record ecological features These will be recorded on a field data sheet and include

- Species encountered/observed,
- Scientific name,
- Common name,
- Qualitative statement on
  - Condition,
  - Abundance,
  - Habitat requirements,
  - Predator/prey species/food habits, and
  - Regulatory status, and
- Species presence will be determined by
  - Visual observation,
  - Vocalization,
  - Burrow/den,

- Nest, and
- Droppings/scat

Quantitative information on wildlife populations will also be obtained in the Stage I field inventory Inventory sampling will include the following procedures

- Live trapping of small mammals will take place both on the hillside and along the South Interceptor Ditch and Woman Creek Trap lines will consist of 25 stations with traps placed at 15m intervals, two to a station and baited with rolled oats or barley Traps will be set for three or four nights and animals caught will be released alive after recording the following
  - Scientific name/ common name,
  - Sex,
  - Reproductive condition,
  - Weight, and
  - Life history stage
- Reptiles will be counted along the same transects used for small mammal trapping The observer will walk the line of the transect and search the ground for reptiles within three to five meters either side of the transect center line Data to be recorded include
  - Species encountered,
  - Activity;
  - Habitat, and
  - Qualitative statement on abundance
- Medium and larger sized mammals will be counted by recording all species along a systematic walk-through of the 881 Hillside, the South Interceptor Ditch and Woman Creek Counting will occur during the small mammal transect trapping Species encountered and activity will be recorded
- Foliage invertebrates will be collected by sweep net and beating Sweep netting involves 10 - 20 strokes through the entire plant taking care not to destroy or injure the shrub, grass or forb being sampled Beating involves a shallow net placed under the parts of a shrub or tree sampled Three to five hard hits on the shrub/tree with a stick knocks the invertebrates to the net below
- Invertebrates will be placed in a killing jar and returned to the laboratory for processing and identification to Order Ground arthropods encountered will be identified to Order in the field, if possible If not, they will be placed in killing jars, returned to the laboratory, processed and identified to Order

  Data to be recorded will include
  - Host plant,
  - Predator/prey species,

- Herbivore, and
- Foodweb location

6 8 4 3 Periphyton

The following method will be employed at the selected locations along Woman Creek, South Interceptor Ditch and Pond C-2 in order to characterize the periphyton communities.

- Surface-floating samplers constructed of styrofoam and a submerged rack containing six plexiglass slides will be used to collect periphyton The upper end of the vertically-suspended slides will be placed about 30 cm below the surface of the water During low-flow periods, the samplers will be suspended at 45° instead of vertically To anchor the sampler in place, sufficient weight will be attached at the end of a cord from the bottom of the sampler (cord length varied depending upon the depth at the sampling site) The exposure period in the field will be 28 +/- 1 days If surface-floating samplers cannot be placed, periphyton will be scraped from substrate (natural)

- For direct cell counts (identification and enumeration), algal growth will be scraped from both sides of the slide and rinsed with distilled water After the sample is diluted (as necessary) and preservative added, a subsample will be taken and allowed to settle for approximately 12 hours in a sedimentation cylinder The dilution volume [usually 200 ml to 1000 milliliters (ml)] and the volume of the subsample (1 ml to 5 ml) are dependent upon the amount of growth on the slide Organisms will be identified to genus and enumerated with a microscope at about 320X.

- Biomass determinations will be made by scraping the growth from both sides of the slide into a pre-weighed crucible The residue is to be dried at 105°C for 12 hours (or until a constant weight is obtained), weighed, and then ashed in a muffle furnace at 600°C for 1 hour and weighed again The difference between the two weights is the ash-free dry weight or organic weight of the sample

- To determine the concentrations of chlorophyll-a and phaeophytin-a, both sides of the slides will be scraped and rinsed with a 90 percent acetone solution, resulting in extract volumes of 20 to 50 ml After the extract is homogenized and steeped for a minimum of 12 hours, it will be clarified by centrifuge tube The absorbance (optical density) of the extract is to be read at 750 and 630 nanometers (nm) in a spectrophotometer If dilution is necessary, 2 ml of the extract will be added to 10 ml of 90 percent acetone solution The amount of phaeophytin-a, a natural degradation product of chlorophyll-a, will be determined by examining the optical density at 633 nm before and after acidification

- All analyses will be completed within five days of the collection of the slides from the field (U S EPA, 1987b)

6 8 4 4 Macrobenthos

Benthic invertebrates are the most common fauna used in ecological assessments of contaminant releases and are defined as the invertebrates retained by screens of mesh size greater than 0 2 millimeters (mm) Two types of sample collectors will be used to obtain macrobenthos samples a Surber sampler with a mesh net and a Ekman grab sampler

At those stations where shallow riffle habitats dominate, a Surber sampler (0 09 m^2 or 1 square-foot) with a 352 micrometers (μm) mesh net will be used Triplicate samples are to be taken on a transect upstream and within 10 m of the designated sampling location. Samples will be placed in small plastic jars and reference specimens preserved in a 70 percent isopropanol solution. Supplemental data on the time the samples are collected, weather conditions, water temperature, depth and general nature of the substrate for each sample, and width of the creek at the transect will also be recorded

At creek locations where the water is shallow and the bottom is soft mud or silt with little current, a pole-mounted Ekman grab sampler will be used The Ekman may also be used with a remote messenger to trigger the sampler Once the sample is obtained, the entire contents will be placed in a large plastic bag and returned to the field laboratory where the contents will be sieved through a No 35 mesh (500 μm) sieve and placed in a large white tray Organisms will be separated from the debris with forceps under a table-mounted magnifier Specimens will be preserved in vials of 70 percent ethanol solution Identification and enumerations, generally to genus, will be made using dissecting microscopes

6 8 4 5 Fish

Fish will be collected in 10- to 25-meter-long collection areas The section will be fished using a Smith-Root backpack shocker The anode on the shocker will be fitted with a nonconducting collection net, and the operator will be assisted by one person equipped with fine-mesh, long-handled dip net for fish capture A standard effort of approximately 900 shocking-seconds will be used to collect the fish An alternative method consists of seining the blocked-off creek sections, one person on each side of the seine The seine is moved along one end to the other with poles on the bottom At the end of a given length of collection area, the seine is lifted from the creek and fish are collected

Block nets will be set across the creek at the upstream and downstream end of the section prior to sampling, and multiple electroshocking passes will be made through the area.

Captured fish will be held in a floating pen until processed Fish will be identified to species, counted, and measured for length (mm) Weights will be determined by water displacement or by spring balance Data will be recorded on standardized field sheets Samples will be taken for laboratory identification/confirmation

Analyses will consist of compiling and summarizing the number, size and weight of each species of fish captured at each sampling site Graphic presentations may include fish length-frequency histograms and plots of catch per effort for each sampling area.

6 8 5 Stage III - Tissue Analysis Sampling Methods

The methodologies selected for tissue analysis studies will depend on the contaminants of concern and their anticipated effects on the selected key receptor species Contaminants of concern and key receptor species will be determined as early as possible in the Stage I planning process It is anticipated that some biota samples collected in the Stage I inventory can be saved and used in the Stage III tissue analysis study Standard protocol for preserving samples for tissue analyses will be followed in those instances where it is anticipated that tissue analyses will be conducted

Analyses for metals and radionuclides in biota may call for a greater biomass of tissue than is available through standard collection methods. At least 55 grams of material (wet weight) is needed per sample for metals analysis, and 1 kilogram (kg) of material is needed for radionuclides For vegetation, roots to 12 inches and above-ground tissues would need to be analyzed separately Obtaining this amount of sample may be impractical for some species of vegetation, or for periphyton, benthos, and macrobenthos It is not the intent of the sampling program to cause unnecessary disturbance or damage to the biota communities in order to collect sufficient samples Any decrease in sample size, however, could make data interpretation more difficult To be meaningful, the number of samples will also need to be large enough to obtain variance estimates DQOs for the tissue sampling program will be evaluated with respect to this determination prior to the Stage I field inventory and during design of the Stage III field sampling plan

It is anticipated that tissue samples collected for contaminant analysis will be sent to a laboratory for the following metals and radionuclide analyses

- Metals determined by Inductively Coupled Argon Plasma Emission Spectroscopy (ICP) (barium, hexavalent chromium, copper and iron),
- Metals determined by Graphite Furnace Atomic Absorption Spectroscopy (GFAA) (arsenic, cadmium, lithium, lead, selenium, strontium and zinc),
- Mercury;
- Uranium 233, 234, 235, 238,
- Americium 241, and
- Plutonium 239, 240

Holding times, preservation methods, sample containers and field and laboratory quality control sample numbers are contained in the QAPjP and shown in Table 6-2

686 Sampling Equipment

The following equipment has been identified for use in the Stage I field surveys and inventory The list is partial and does not include the specialized laboratory equipment necessary for toxicological analyses

Vegetation Sampling

- 30 m and 100 m flexible tape,
- Brunton compass,
- 1 m rule,
- 1 m^2 quadrat frames,
- 1/4 m^2 quadrat frames,
- Survey stakes or rebar for transect locations,
- Small sledge hammer;
- Field forms and clipboards,
- Plant press,

TABLE 6-2

HOLDING TIMES, PRESERVATION METHODS, AND SAMPLE CONTAINERS FOR BIOTA SAMPLES

	Maximum Holding Time From Date Collected	Preservation Method	Container	Approximate Sample Size
SAMPLES FOR METALS ANALYSES				
TERRESTRIAL VEGETATION				
- Metals Determined by ICP**	6 mos	Freeze & ship w/dry ice	Paper bag inserted into plastic bag and sealed	25 g
- Metals Determined by GFAA**	6 mos.	Freeze & ship w/dry ice	Paper bag inserted into plastic bag and sealed	25 g
- Hexavalent Chromium	24 hours	Freeze & ship w/dry ice	Paper bag inserted into plastic bag and sealed	25 g
- Mercury	28 days	Freeze & ship w/dry ice	Paper bag inserted into plastic bag and sealed	5 g
Periphyton and Benthic Macroinvertibrates				
- Metals Determined by ICP	6 mos	Freeze & ship w/dry ice	Plastic	25 g
- Metals Determined by GFAA	6 mos	Freeze & ship w/dry ice	Plastic	25 g
- Hexavalent Chromium	24 hours	Freeze & ship w/dry ice	Plastic	25 g
- Mercury	28 days	Freeze & ship w/dry ice	Plastic	5 g
SAMPLES FOR RADIONUCLIDE ANALYSES				
Terrestrial Vegetation				
- Uranium 223, 2234, 235, 238 Americium 241 Plutonium 239, 240	6 mos	Freeze & ship w/dry ice	Paper bag inserted into plastic bag and sealed	1 kg

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TABLE 6-2 (continued)

HOLDING TIMES, PRESERVATION METHODS, AND SAMPLE CONTAINERS FOR BIOTA SAMPLES

	Maximum Holding Time From Date Collected	Preservation Method	Container	Approximate Sample Size
SAMPLES FOR RADIONUCLIDE ANALYSES (continued)				
<u>Periphyton and Benthic Macroinvertebrates</u>				
- Uranium 233, 234, 245, 238 Americium 241 Plutonium 239, 240	6 mos	Freeze & ship w/dry ice	Plastic	1 kg

* Sample size may vary with specific laboratory requirements

**ICP = Inductively Coupled Argon Plasma Emission Spectroscopy Metals to be determined include Ba, Cr, Cu, and Fe.

+GFAA = Graphite Furnace Atomic Absorption Spectroscopy Metals to be determined include As, Cd, Li, Pg, Se, and Sr.

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- Triple beam balance,
- Dissecting scope,
- Paper collection bags, and
- Drying oven

Terrestrial Wildlife Sampling

- Binoculars,
- Smith live traps,
- Sweep nets,
- Killing jar;
- Absorbent material,
- Field forms and clipboard, and
- Pill boxes

Aquatic Sampling

- Surber sampler;
- Ekman grab,
- Artificial substrate rack with glass slides,
- Styrofoam floats,
- No 35 mesh brass screen,
- No 60 mesh brass screen,
- Forceps and glass vials,
- 70% ethanol,
- Dry ice and sample coolers,

- Permanent markers, and
- One gallon zip-loc plastic bags

The following equipment will be used for preservation of vegetation samples for Stage III tissue analysis

- 1 m^2 quadrat frames,
- Shears for tissue clipping,
- Small spade for root collection,
- Knife,
- One gallon plastic zip-loc bags,
- Large paper sacks,
- Permanent markers,
- Dry ice,
- Coolers, and
- Freezer

SECTION 7

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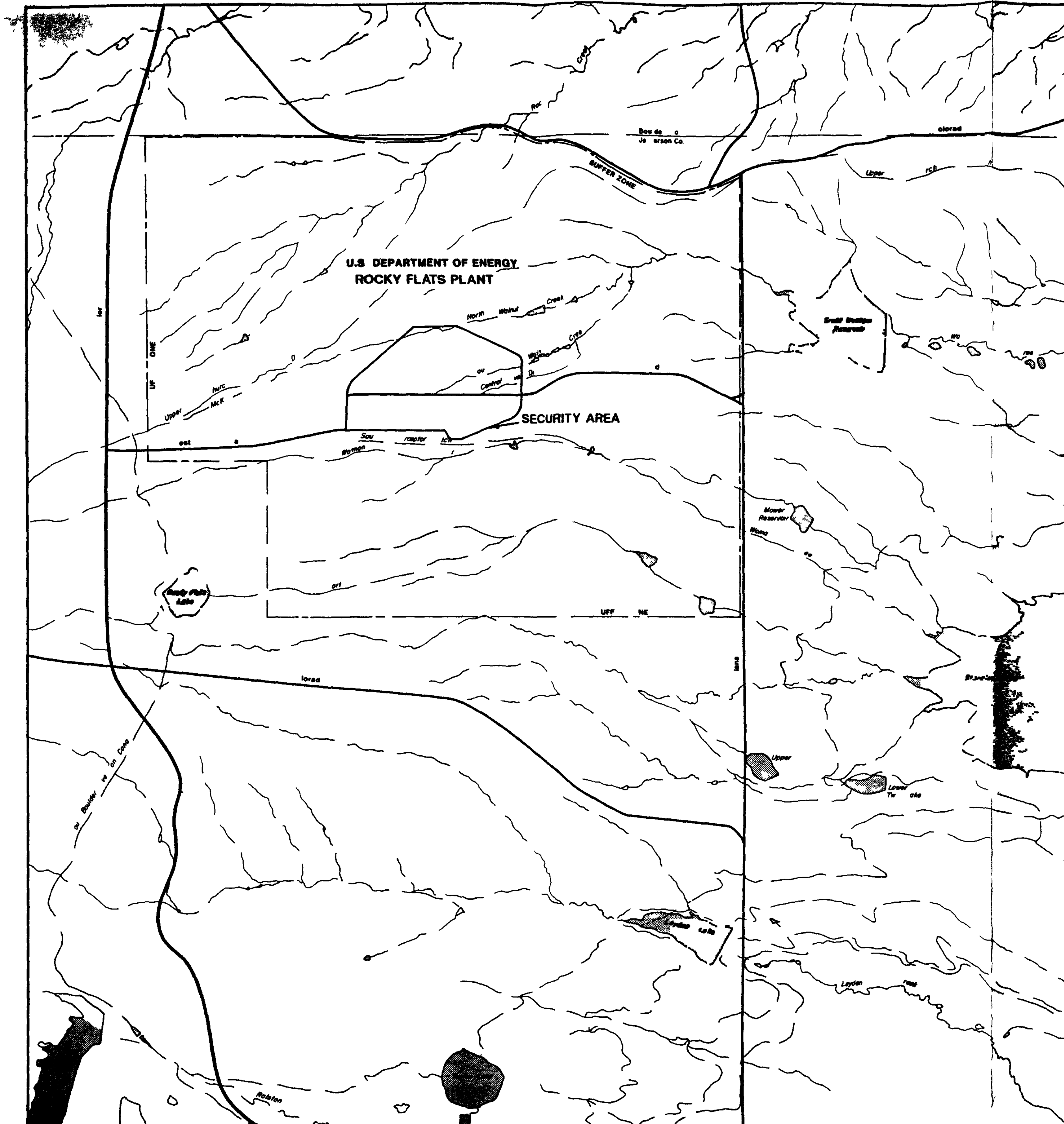
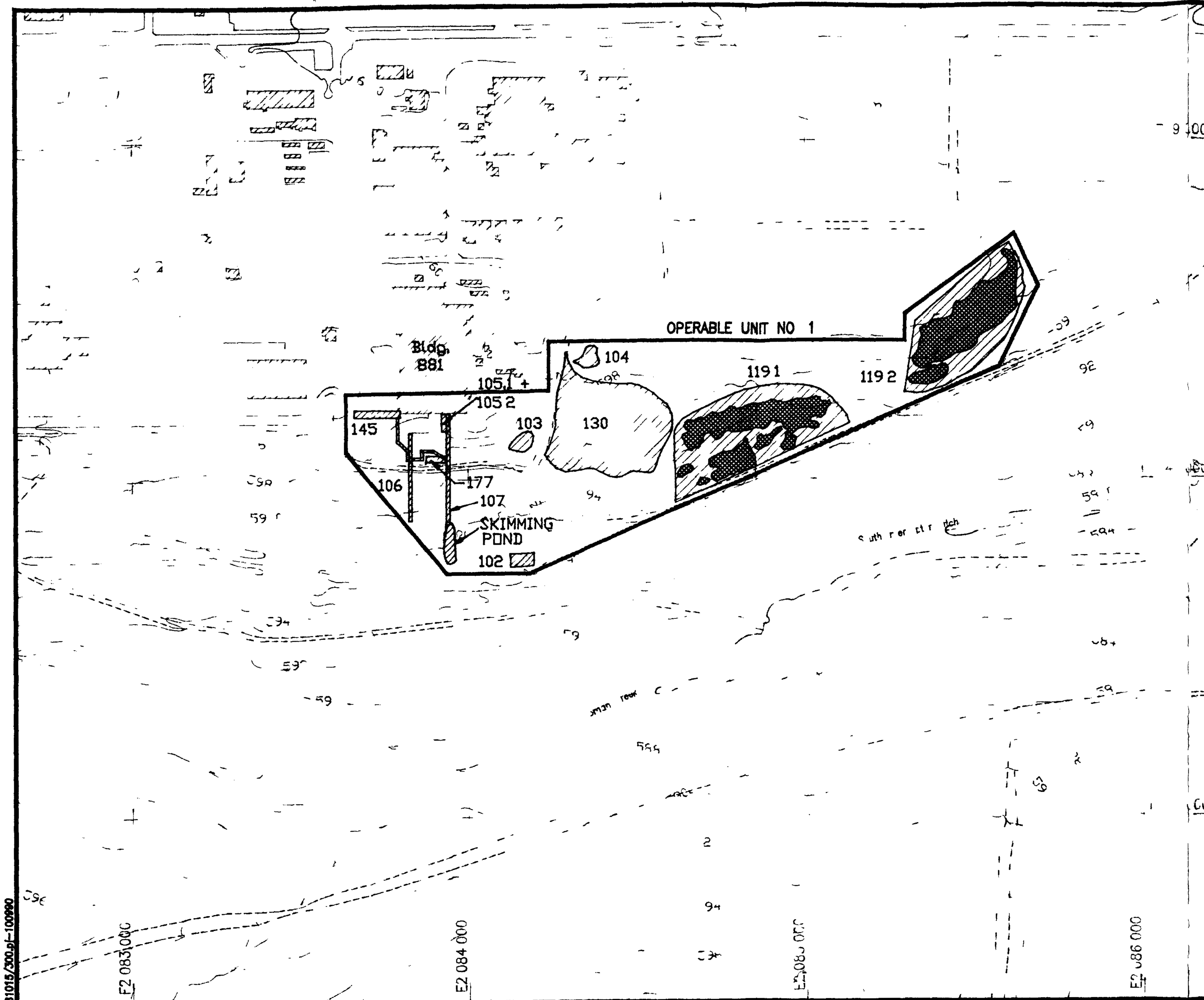


(after USGS Quads Louisville 1979
Golden 1980 Lafayette 1979)

FIGURE 1–2

ROCKY FLATS PLANT BOUNDARIES AND BUFFER ZONE



EXPLANATION

Individual Hazardous Substance Site (IHSS)

145 IHSS Designation

Maximum Extent of IHSS 119 Barrel Storage Based on Aerial Photographs dated 04/29/67 04/10/68 05/24/69 and 03/30/71

Scale 1 = 300

0' 150' 300'

CONTOUR INTERVAL = 20'

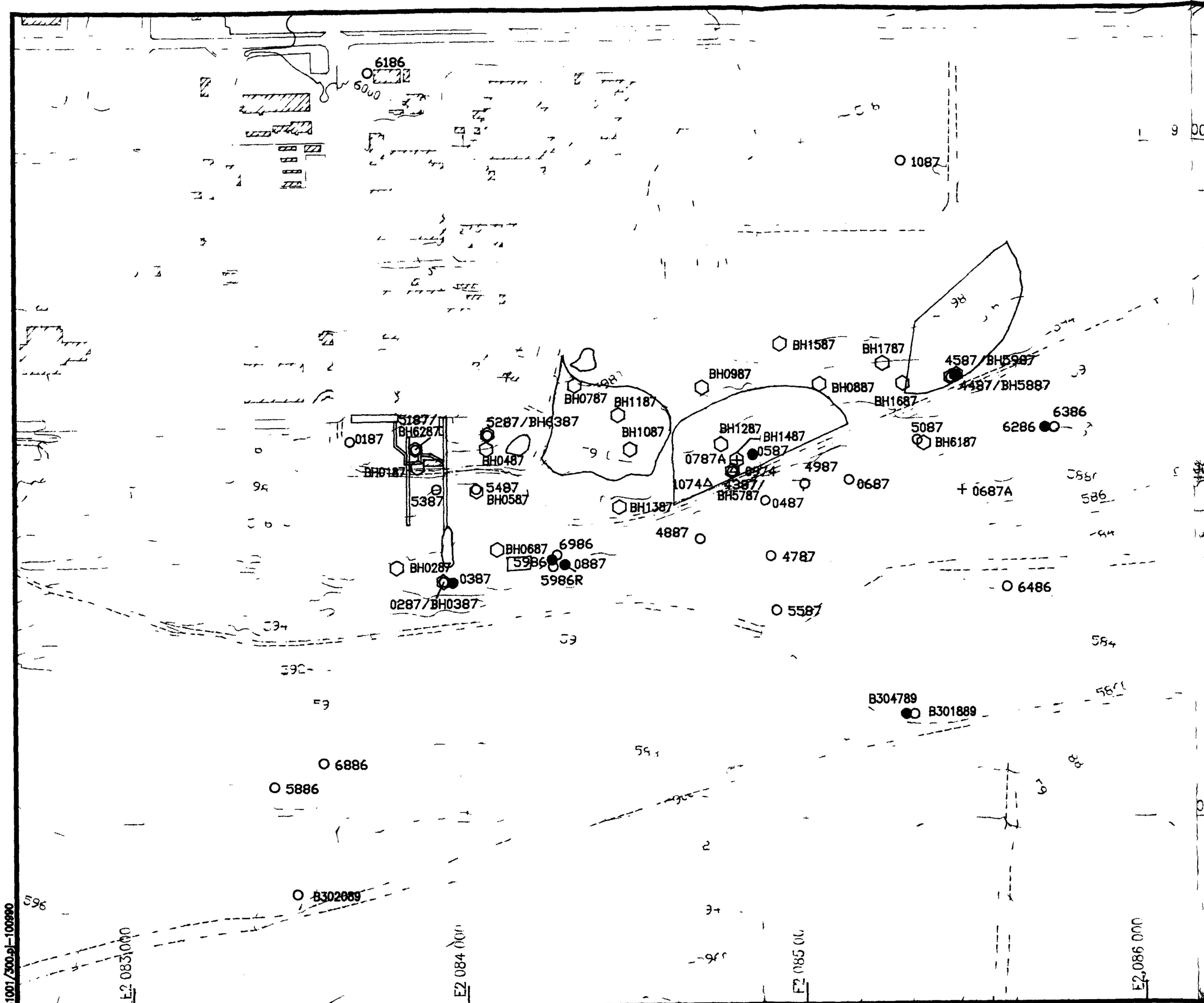
U S DEPARTMENT OF ENERGY
Rocky Flats Plant
Golden Colorado

OPERABLE UNIT NO 1
PHASE III RFI/RI WORK PLAN

FIGURE 1-5

INDIVIDUAL HAZARDOUS SUBSTANCE SITE LOCATIONS

October 1990



EXPLANATION

	▭	Individual Hazardous Substance Site (IHSS)
B301889	○	Alluvial Monitoring Well
B304789	●	Bedrock Monitoring Well
0271	△	Pre-1986 Well
1187A	+	Abandoned Hole
BH0987	⬡	Borehole

N

Scale 1 = 300

0' 150' 300'

CONTOUR INTERVAL = 20'

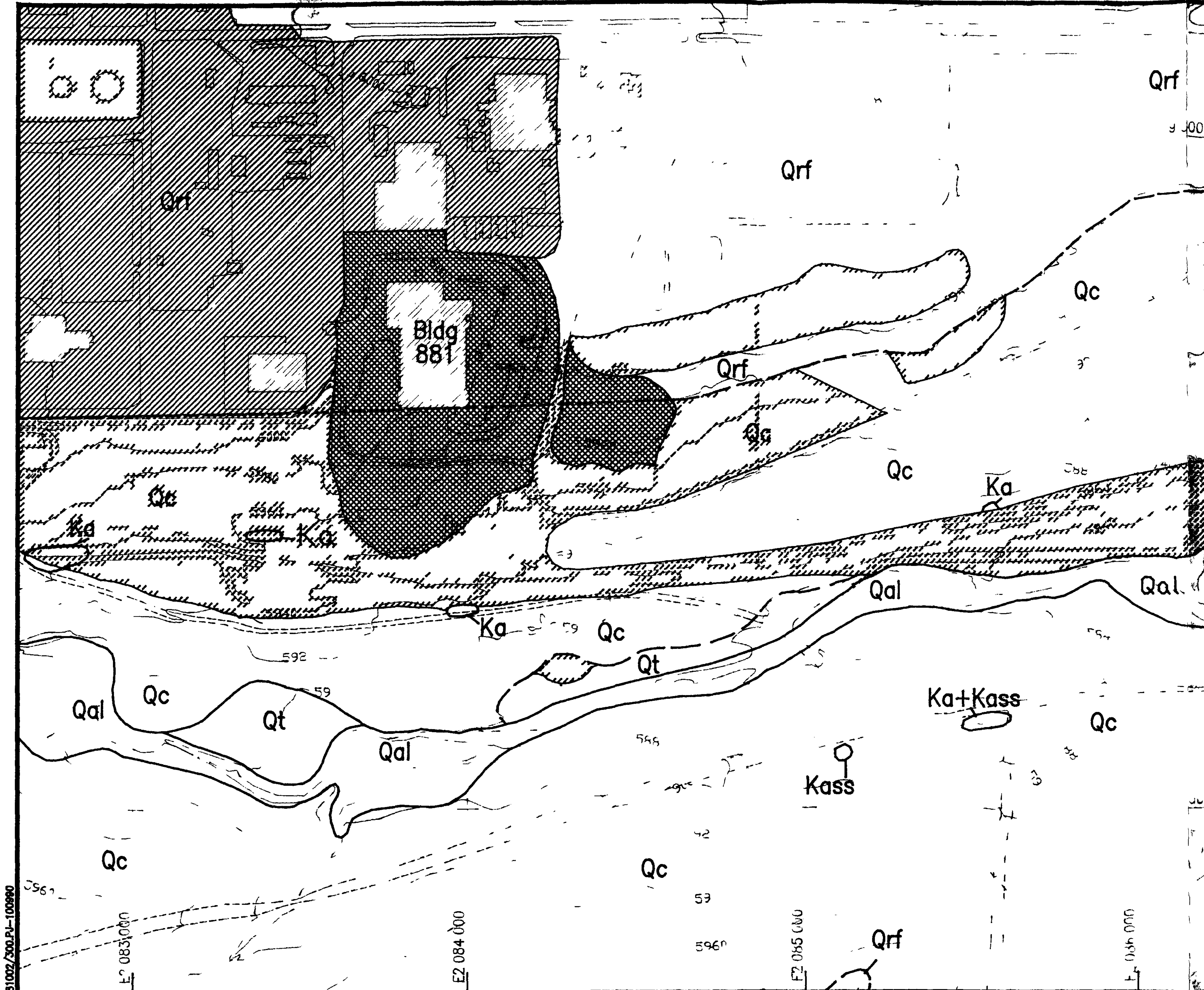
U S DEPARTMENT OF ENERGY
Rocky Flats Plant
Golden, Colorado

OPERABLE UNIT NO 1
PHASE III RFI/RI WORK PLAN

FIGURE 2-1

PHASE I AND PHASE II RI
BOREHOLE AND MONITOR WELL
LOCATIONS

October 1990



EXPLANATION

Artificial Fill
Pavement or Gravel
Disturbed Ground
Qal Recent Valley Fill
Qc Colluvium
Qt Terrace Alluvium
Qrf Rocky Flats Alluvium
Ka Arapahoe Formation Claystone
Kass Arapahoe Formation Sandstone
Geologic contact dashed where approximately located

Scale 1 = 300
0' 150' 300'
CONTOUR INTERVAL = 20'

U S DEPARTMENT OF ENERGY
Rocky Flats Plant
Golden Colorado

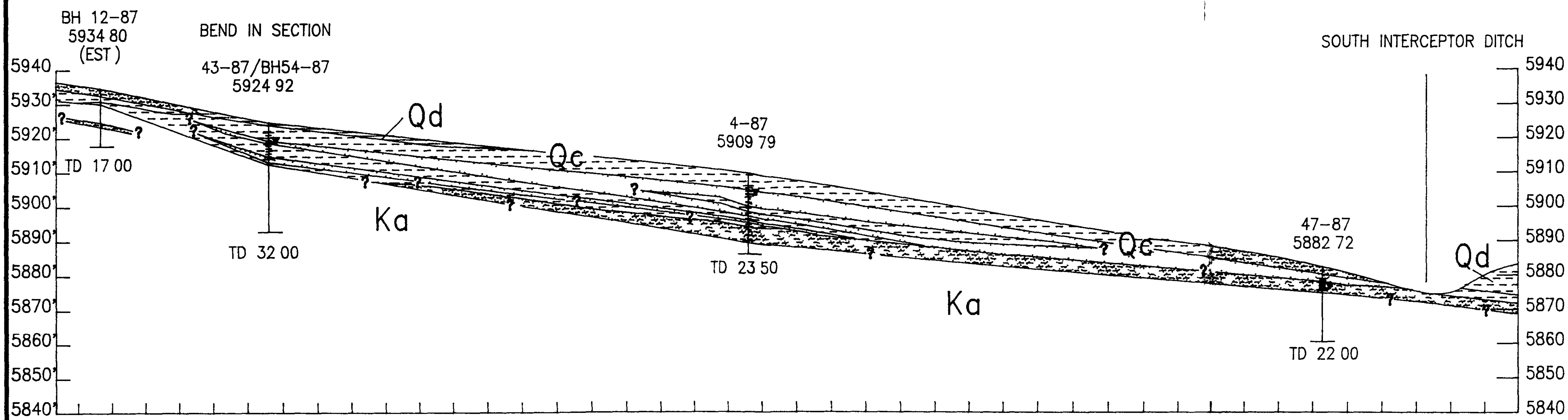
OPERABLE UNIT NO 1
PHASE III RFI/RI WORK PLAN

FIGURE 2-2

SURFICIAL GEOLOGY

October 1990

881002/300.PJ-100990



EXPLANATION

Scale 1 =30

43-87/BH54-87	Well/Borehole Identification
5924 92	Ground Surface Elevation (Surveyed)
	Water Level (Measured 2/4/88)
	Geologic Contact (Querried where inferred Dashed where approximately located)
	Screened Interval
TD 32 00	Total Depth Drilled

QUATERNARY

Qt	Terrace
Qd	Disturbed Ground
Qc	Colluvium
Qrf	Rocky Flats Alluvium
Qal	Alluvium

CRETACEOUS

Ka	Arapahoe Formation (Claystone)
Kass	Arapahoe Formation (Sandstone)

Clay

Clayey Sand or Sandy Clay

Cobbles and/or Gravel

Silt or Siltstone

NOTE Geology inferred between data points

U S DEPARTMENT OF ENERGY
Rocky Flats Plant
Golden Colorado

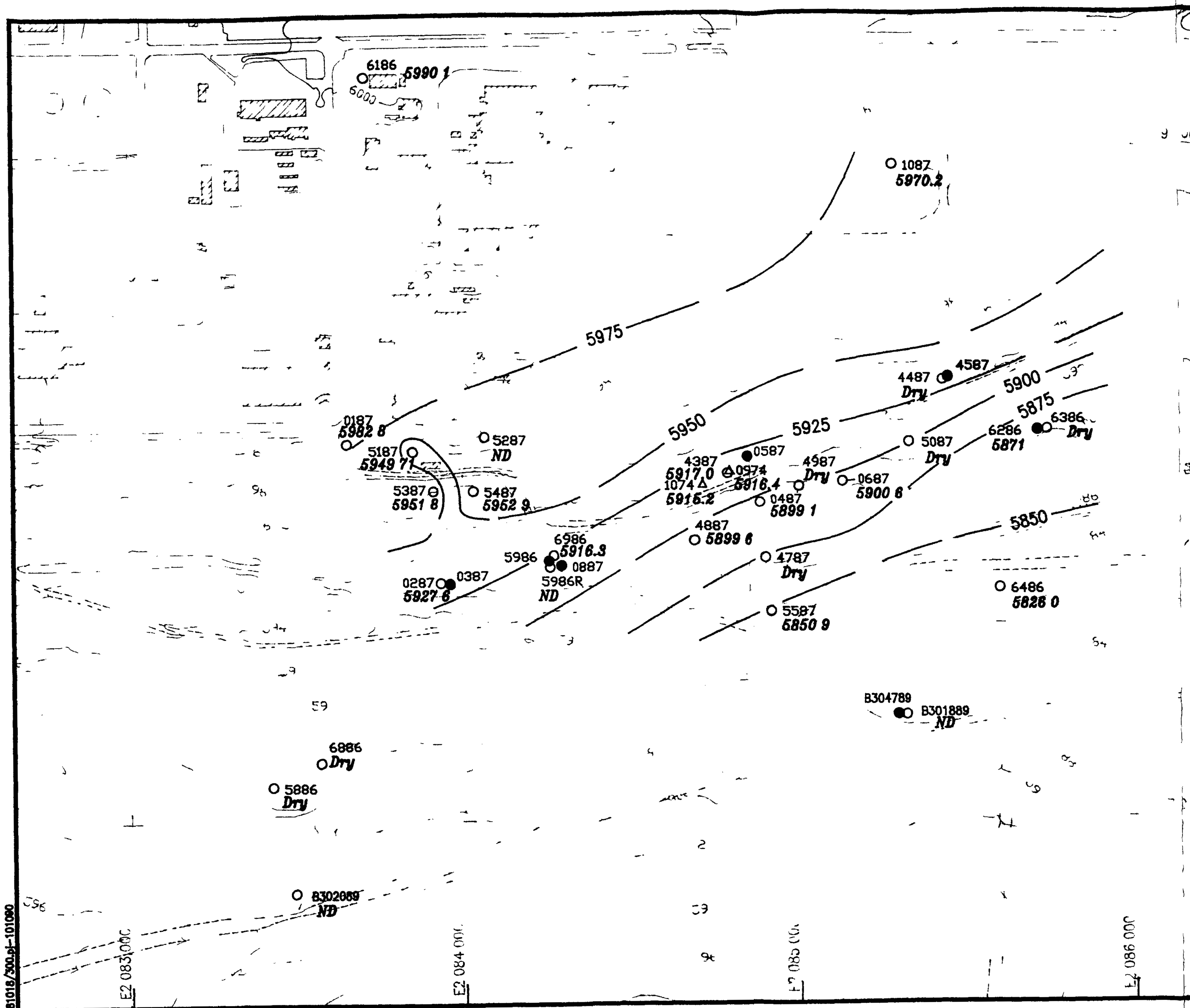
OPERABLE UNIT NO 1
PHASE III RFI/RI WORK PLAN

FIGURE 2-3

CROSS SECTION A - A

October 1990

881022/1 pl-101090



EXPLANATION

B301889 ○ Alluvial Monitoring Well

B304789 ● Bedrock Monitoring Well

0271 △ Pre-1986 Well

5851 Water Table Elevation (feet above mean sea level)

5920 Line of Equal Water Table Elevation (feet above sea level – dashed where approximately located)

ND No Data

Scale 1 = 300

0' 150' 300'

CONTOUR INTERVAL = 20'

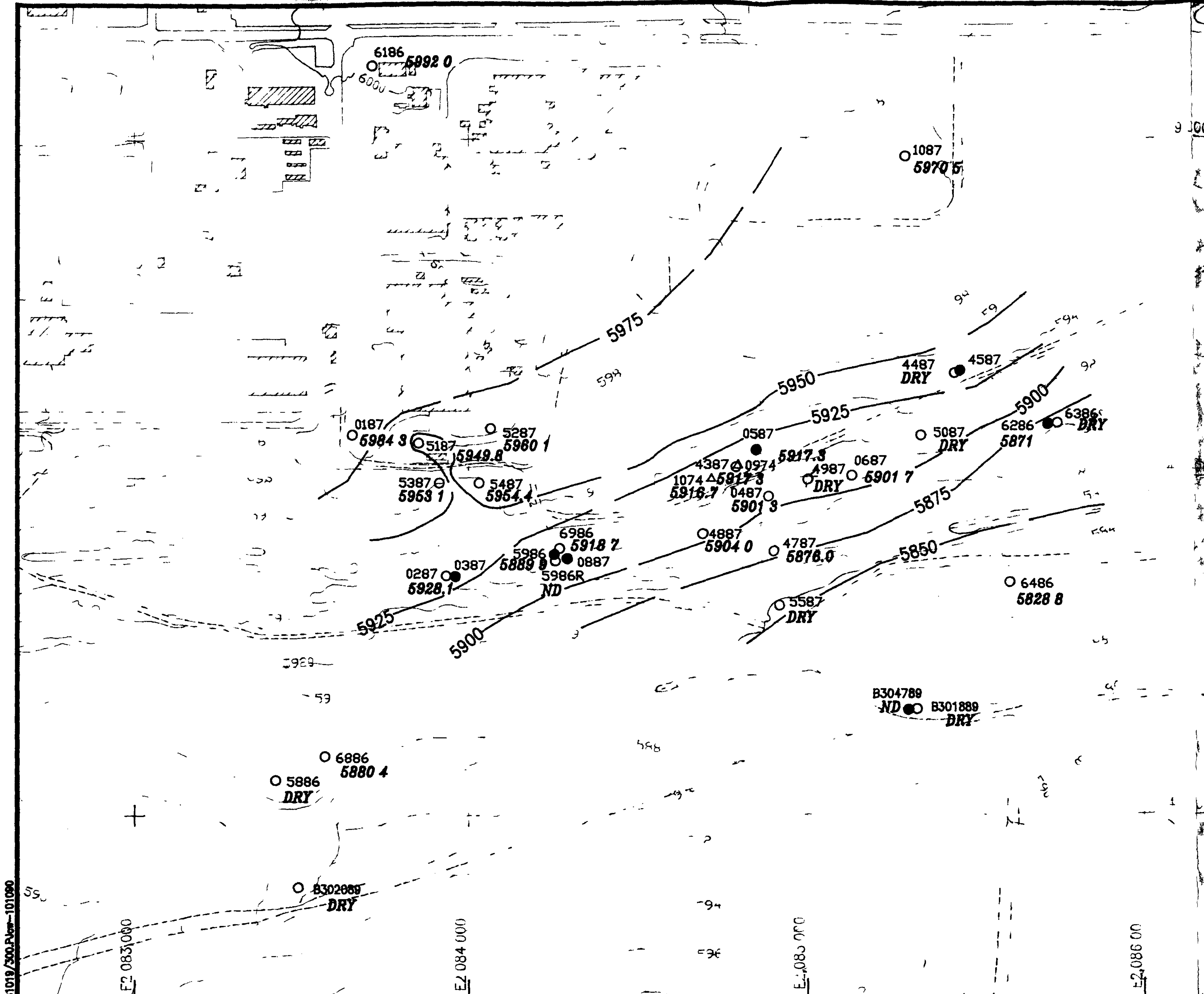
U S DEPARTMENT OF ENERGY
Rocky Flats Plant
Golden Colorado

OPERABLE UNIT NO 1
PHASE III RFI/RI WORK PLAN

FIGURE 2-4

ELEVATION OF WATER TABLE
January 1989

October 1990



EXPLANATION

B301889 ○ Alluvial Monitoring Well

B304789 ● Bedrock Monitoring Well

0271 △ Pre-1986 Well

5851 Water Table Elevation (feet above mean sea level)

5920 Line of Equal Water Table Elevation (feet above sea level – dashed where approximately located)

ND No Data

Scale 1 = 300

0' 150' 300'

CONTOUR INTERVAL = 20'

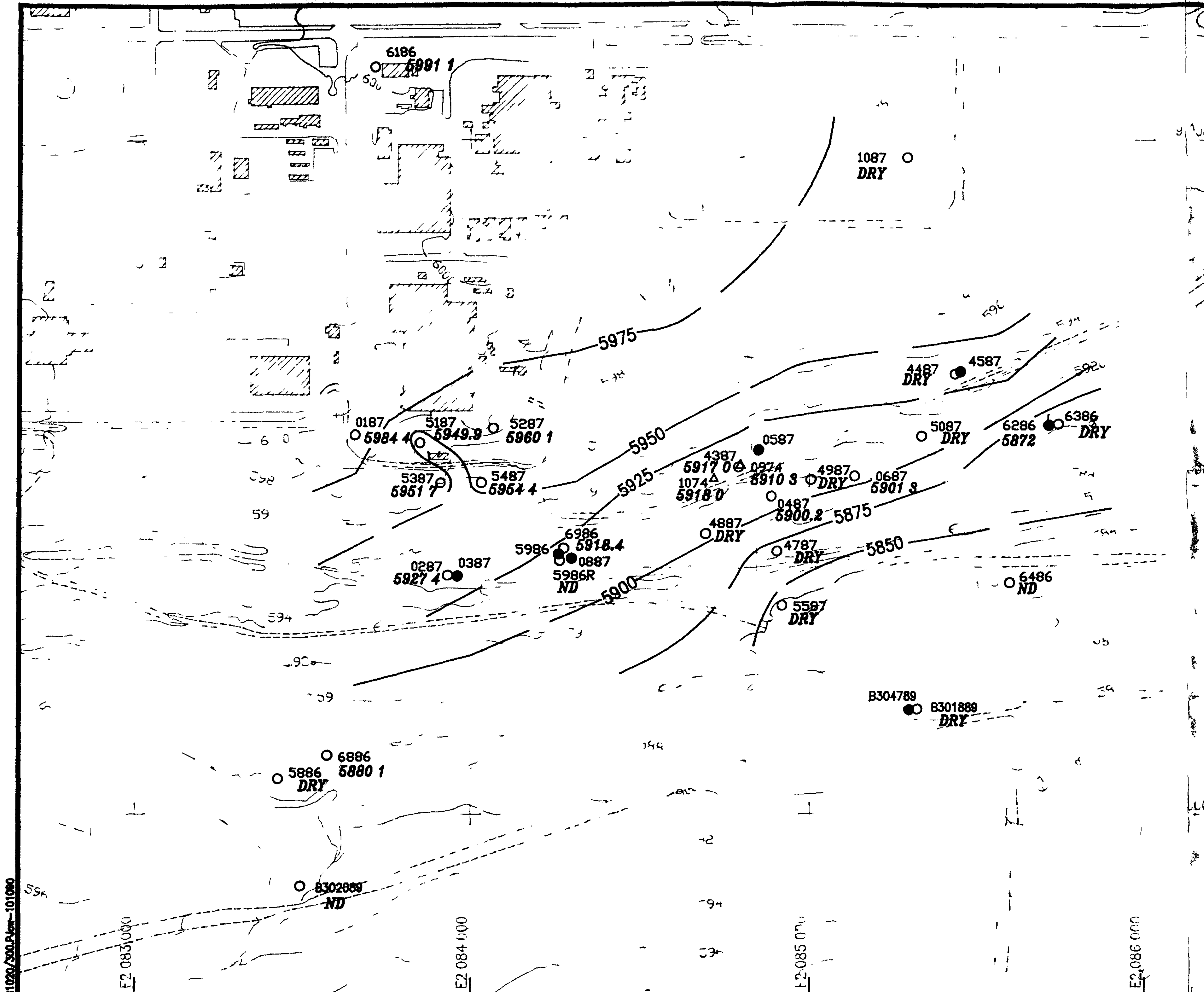
U S DEPARTMENT OF ENERGY
Rocky Flats Plant
Golden, Colorado

OPERABLE UNIT NO 1
PHASE III RFI/RI WORK PLAN

FIGURE 2-5

ELEVATION OF WATER TABLE
May 1989

October 1990



EXPLANATION

B301889 ○ Alluvial Monitoring Well

B304789 ● Bedrock Monitoring Well

0271 △ Pre-1986 Well

5851 Water Table Elevation (feet above mean sea level)

5920 Line of Equal Water Table Elevation (feet above sea level – dashed where approximately located)

ND No Data

Scale 1 = 300

0' 150' 300'

CONTOUR INTERVAL = 20'

U S DEPARTMENT OF ENERGY
Rocky Flats Plant
Golden, Colorado

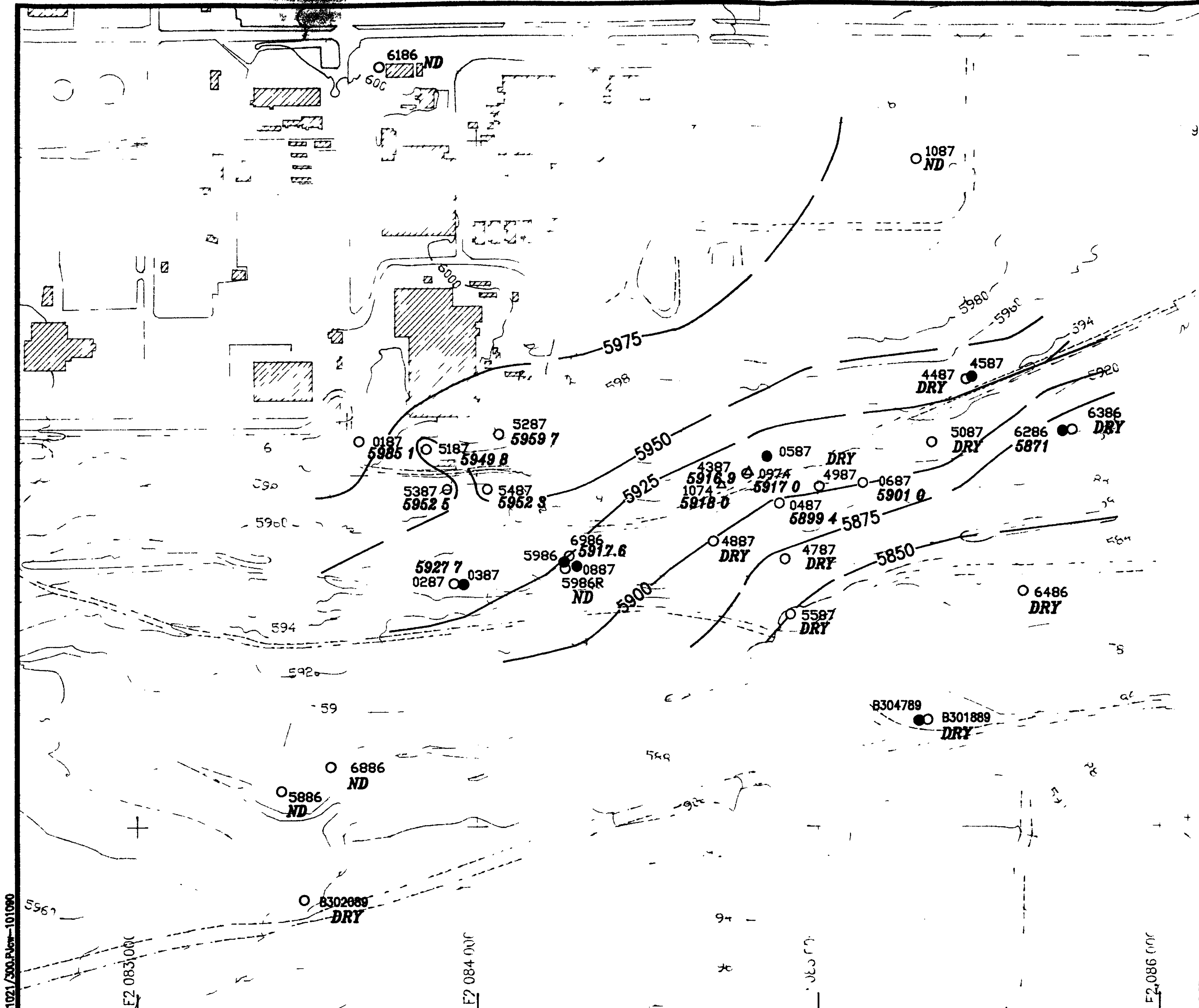
OPERABLE UNIT NO 1
PHASE III RFI/RI WORK PLAN

FIGURE 2-6

ELEVATION OF WATER TABLE
August 1989

October 1990

881020/300.PJew-101090



EXPLANATION

B301889	○	Alluvial Monitoring Well
B304789	●	Bedrock Monitoring Well
0271	△	Pre-1986 Well
5851		Water Table Elevation (feet above mean sea level)
5920		Line of Equal Water Table Elevation (feet above sea level — dashed where approximately located)
ND		No Data

Scale 1 = 300

0' 150' 300'

CONTOUR INTERVAL = 20'

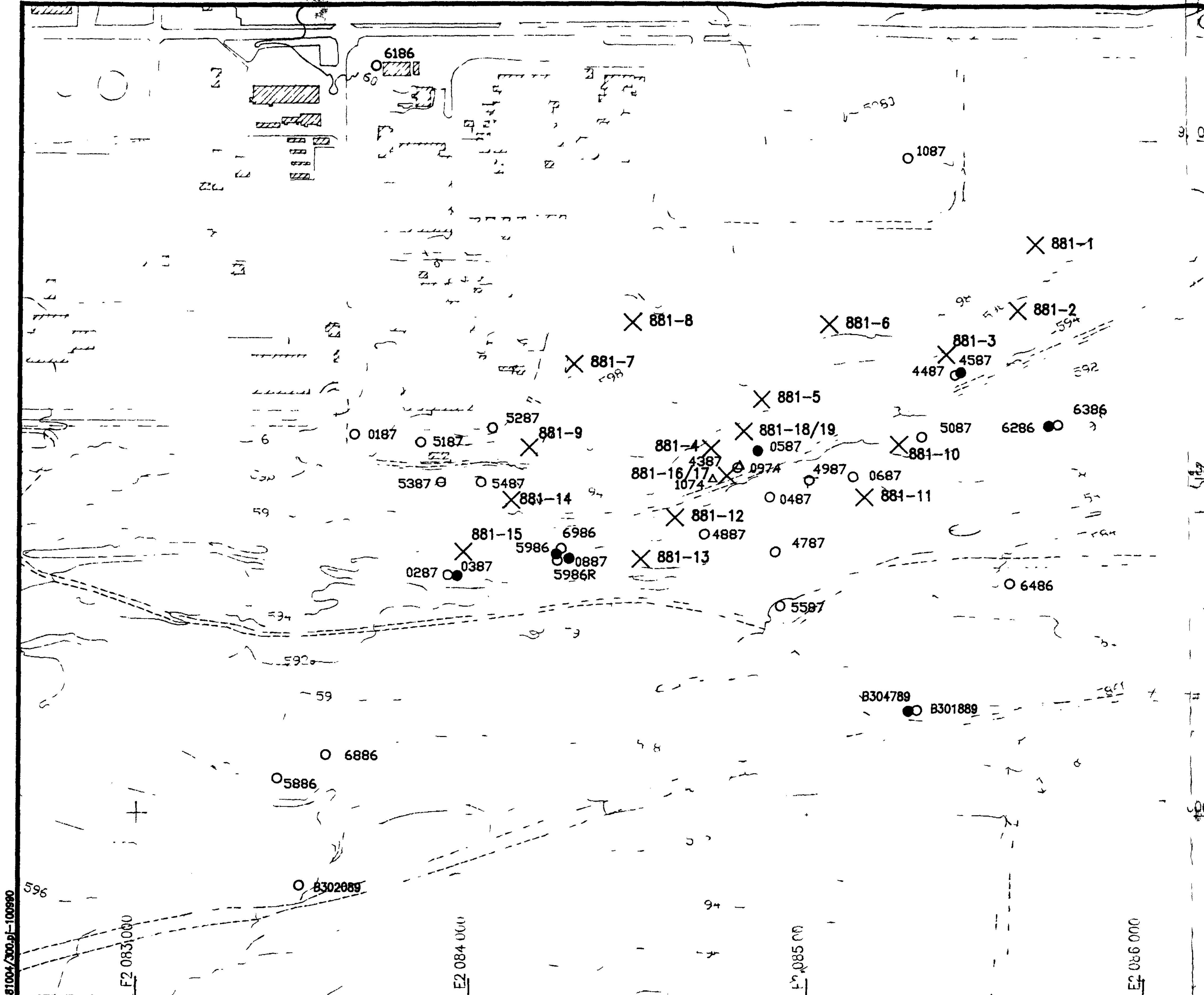
U S DEPARTMENT OF ENERGY
Rocky Flats Plant
Golden, Colorado

OPERABLE UNIT NO 1
PHASE III RFI/RI WORK PLAN

FIGURE 2-7

ELEVATION OF WATER TABLE
October 1989

October 1990



EXPLANATION

B301889 O Alluvial Monitoring Well

B304789 ● Bedrock Monitoring Well

0271 △ Pre-1986 Well

X 881-1 Approximate Surface Soil Scrape Location

Scale 1 = 300

0' 150' 300'

CONTOUR INTERVAL = 20'

U S DEPARTMENT OF ENERGY
Rocky Flats Plant
Golden, Colorado

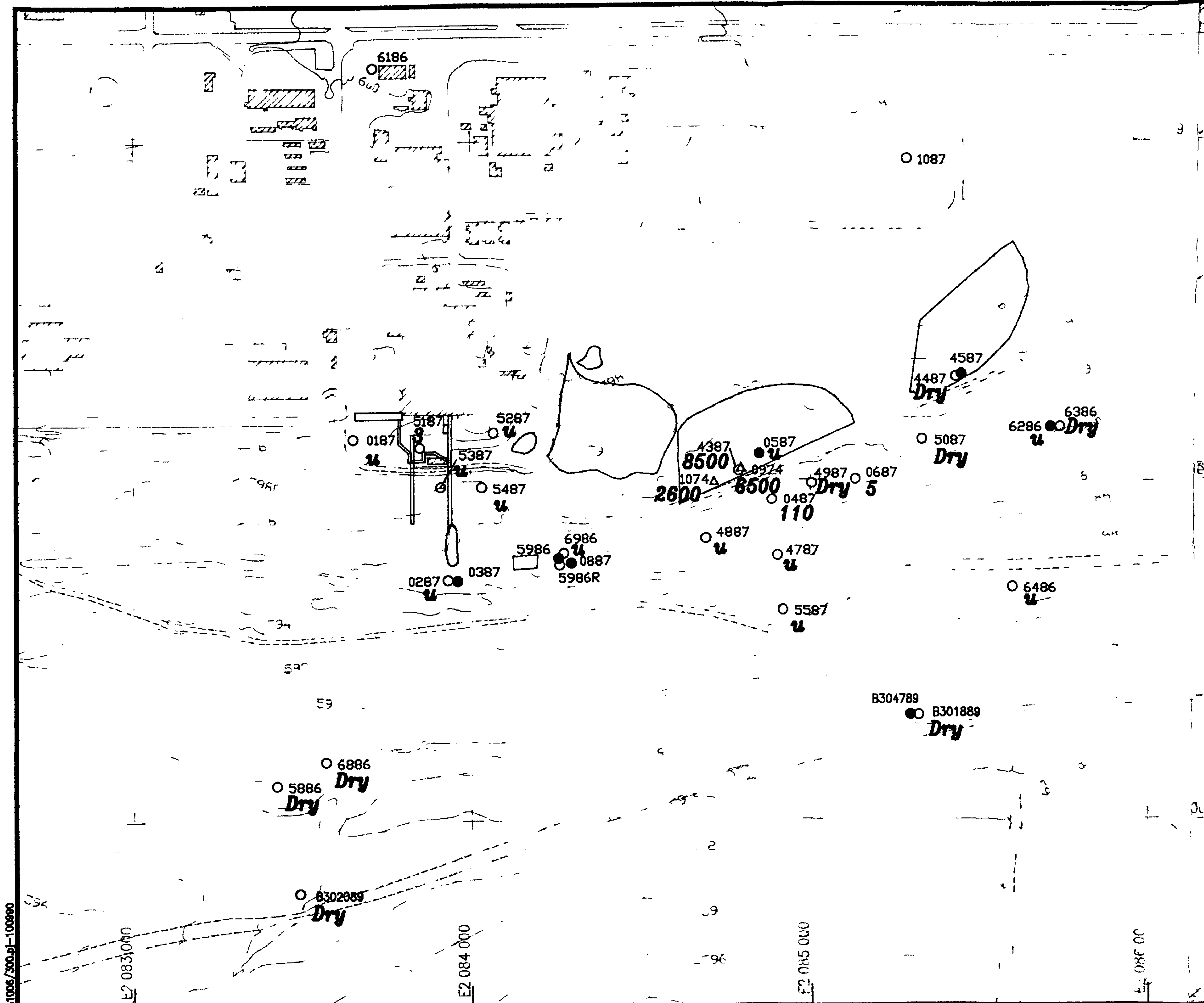
OPERABLE UNIT NO 1
PHASE III RFI/RI WORK PLAN

FIGURE 2-8

SURFACE SCRAPE SAMPLING LOCATIONS
September, 1988

October 1990

881004/300.pl-100990



EXPLANATION

Individual Hazardous Substance Site (IHSS)

B301889 O Alluvial Monitoring Well

B304789 ● Bedrock Monitoring Well

0271 Δ Pre-1986 Well

Trichloroethene Concentration

35 Data in $\mu g/l$

u Analyzed but not Detected

N

Scale 1 = 300

0' 150' 300'

CONTOUR INTERVAL = 20'

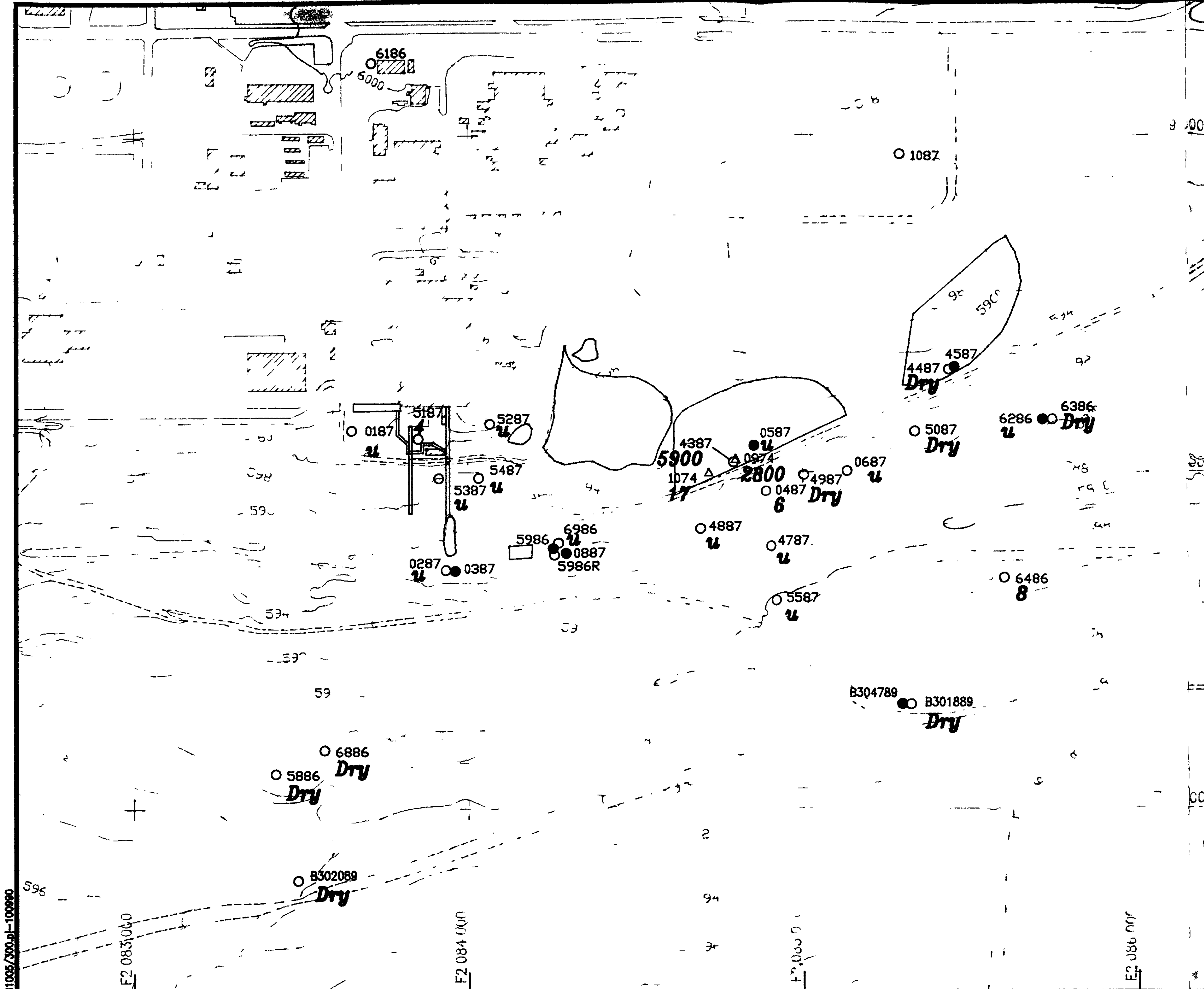
U S DEPARTMENT OF ENERGY
Rocky Flats Plant
Golden, Colorado

OPERABLE UNIT NO 1
PHASE III RFI/RI WORK PLAN

FIGURE 2-9

TRICHLOROETHENE CONCENTRATIONS IN THE UNCONFINED GROUND-WATER FLOW SYSTEM
Second Quarter 1989

October 1990



EXPLANATION

Individual Hazardous Substance Site (IHSS)

B301889 ○ Alluvial Monitoring Well

B304789 ● Bedrock Monitoring Well

0271 △ Pre-1986 Well

Tetrachloroethene Concentrations

6 Data in µg/l

u Analyzed but not Detected

Scale 1 = 300

0' 150' 300'

CONTOUR INTERVAL = 20'

U S DEPARTMENT OF ENERGY
Rocky Flats Plant
Golden Colorado

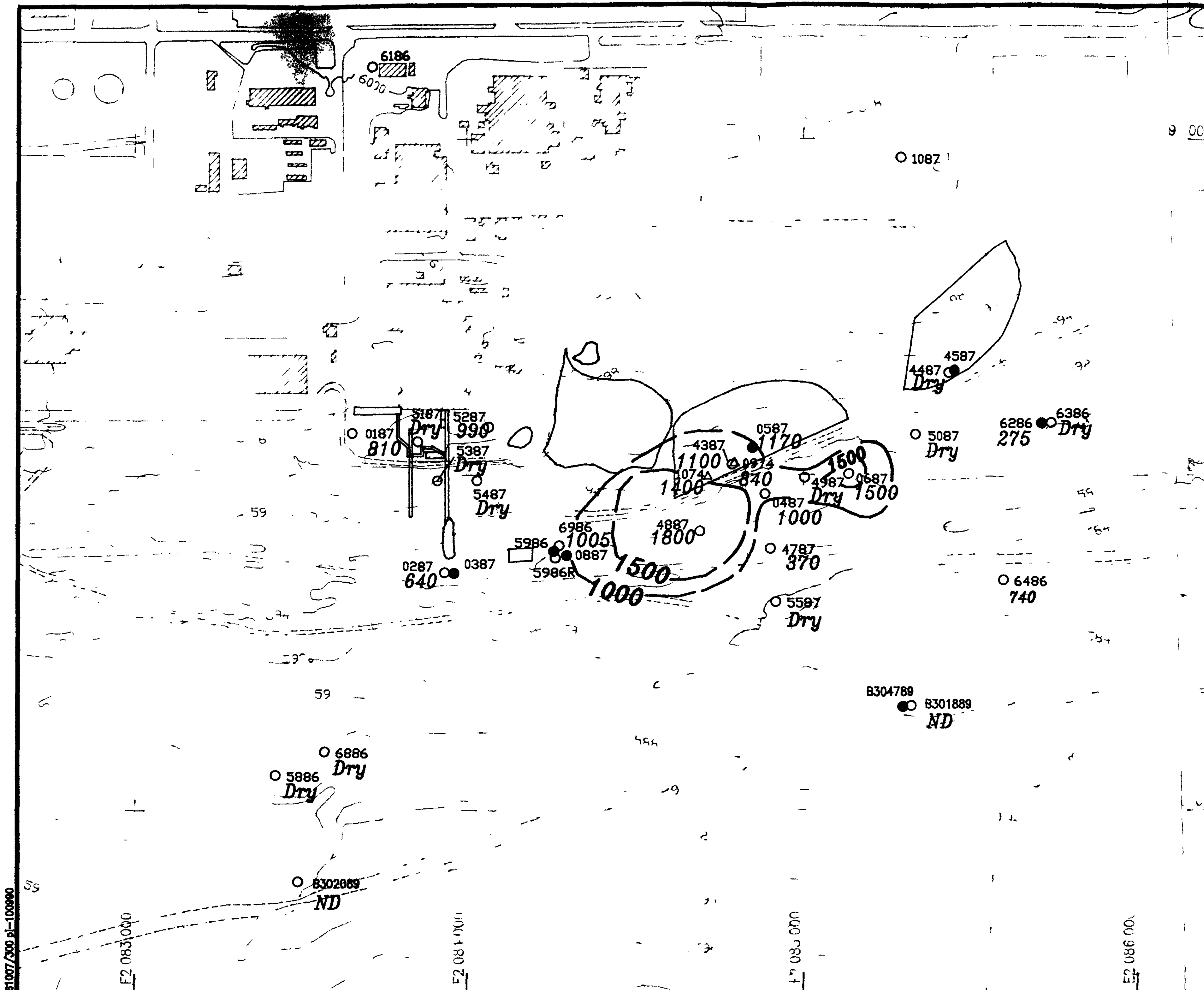
OPERABLE UNIT NO 1
PHASE III RFI/RI WORK PLAN

FIGURE 2-10

TETRACHLOROETHENE CONCENTRATIONS IN THE UNCONFINED GROUND-WATER FLOW SYSTEM
Second Quarter 1989

October 1990

881005/300.pl-100990



EXPLANATION

Individual Hazardous Substance Site (IHSS)

B301889 O Alluvial Monitoring Well

B304789 ● Bedrock Monitoring Well

0271 Δ Pre-1986 Well

1187A + Abandoned Hole

997 Data in mg/l

1,000 Line of Equal TDS Concentration – Dashed where Approximately Located

ND No Data

Scale 1 = 300

0' 150' 300'

CONTOUR INTERVAL = 20'

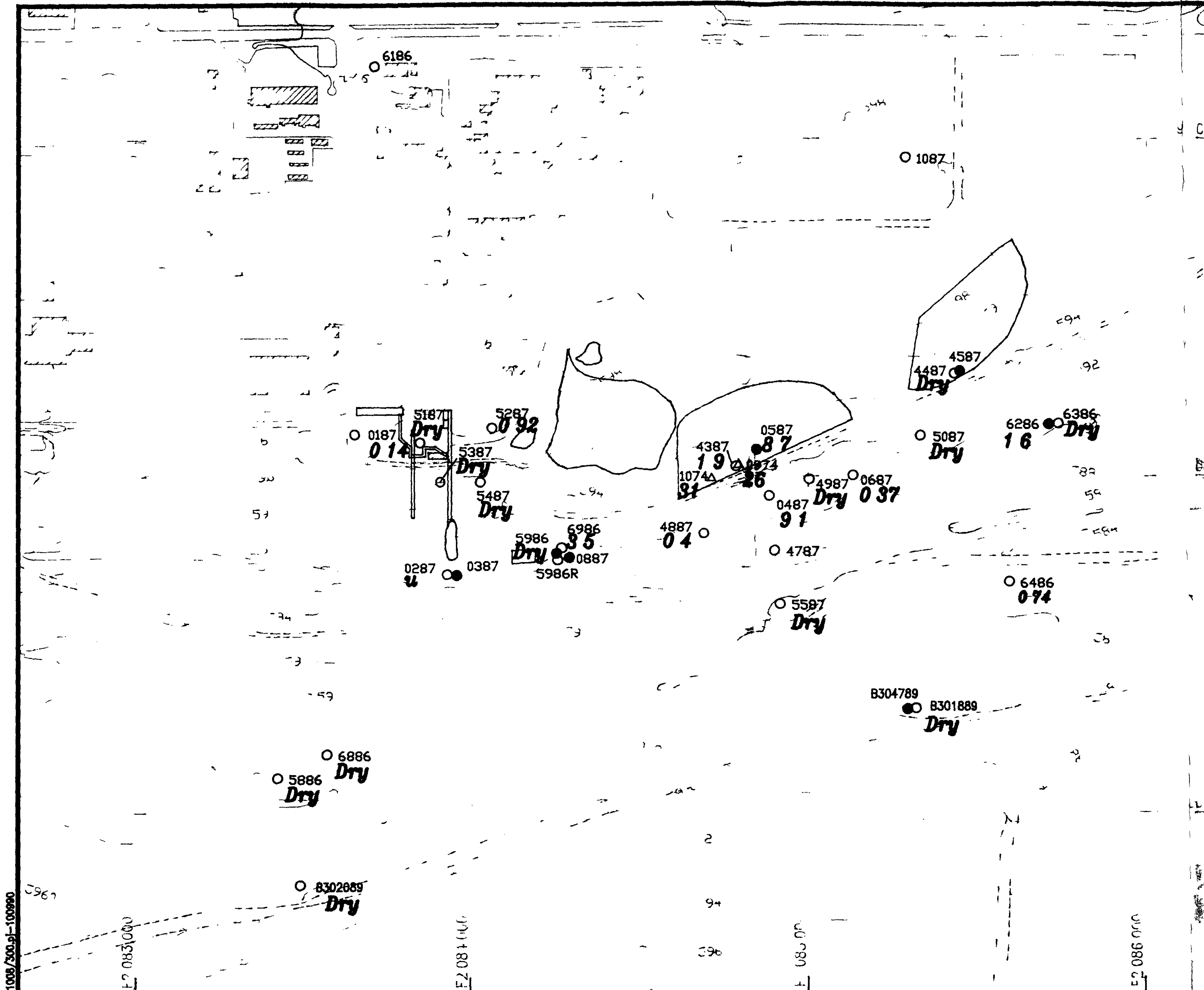
U S DEPARTMENT OF ENERGY
Rocky Flats Plant
Golden Colorado

OPERABLE UNIT NO 1
PHASE III RFI/RI WORK PLAN

FIGURE 2-11

TOTAL DISSOLVED SOLIDS (TDS)
ISOPLETHS FOR THE UNCONFINED
GROUND-WATER FLOW SYSTEM
Second Quarter 1989

October 1990



EXPLANATION

Individual Hazardous Substance Site (IHSS)

B301889 ○ Alluvial Monitoring Well

B304789 ● Bedrock Monitoring Well

0271 △ Pre-1986 Well

Nitrate Concentrations

8 7 Data in mg/l

u Analyzed but not Detected

Scale 1 = 300

0' 150' 300'

CONTOUR INTERVAL = 20'

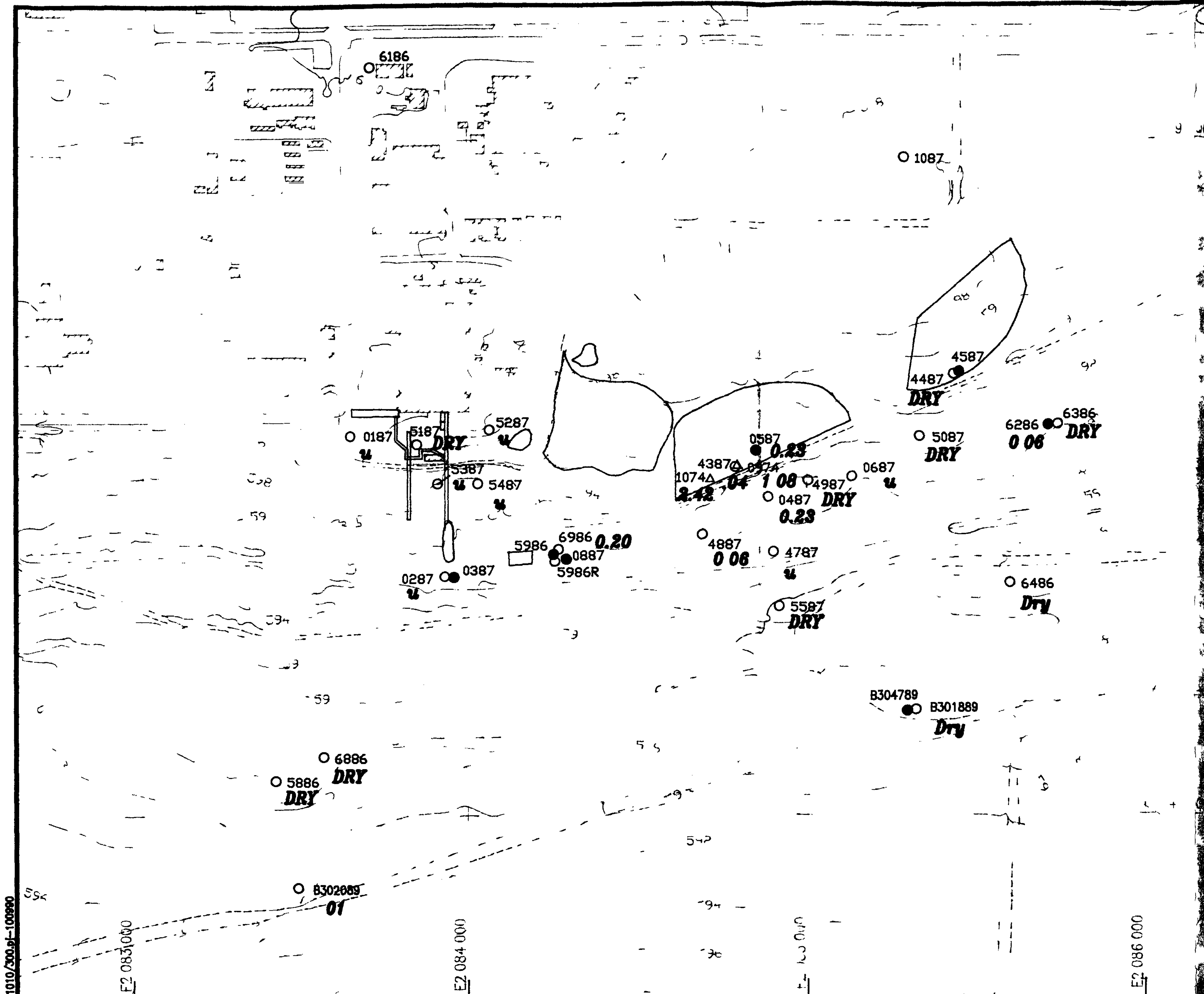
U S DEPARTMENT OF ENERGY
Rocky Flats Plant
Golden, Colorado

OPERABLE UNIT NO 1
PHASE III RFI/RI WORK PLAN

FIGURE 2-12

NITRATE CONCENTRATIONS IN THE UNCONFINED GROUND-WATER FLOW SYSTEM
Second Quarter 1989

October 1990



EXPLANATION

Individual Hazardous Substance Site (IHSS)

B301889 O Alluvial Monitoring Well

B304789 ● Bedrock Monitoring Well

0271 △ Pre-1986 Well

Selenium Concentrations

0 5 Data in mg/l

u Analyzed but not Detected

Scale 1 = 300

0' 150' 300'

CONTOUR INTERVAL = 20'

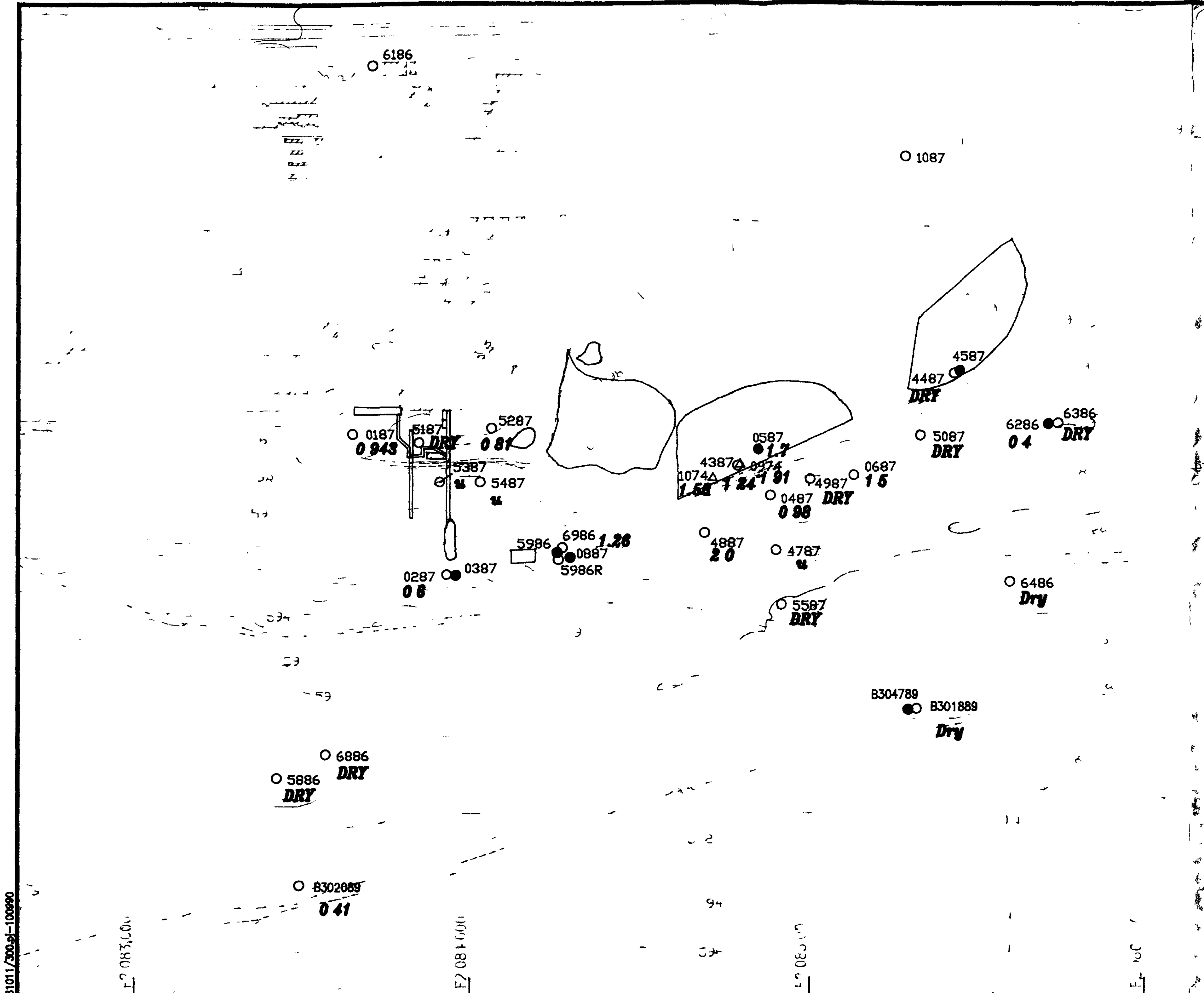
U S DEPARTMENT OF ENERGY
Rocky Flats Plant
Golden Colorado

OPERABLE UNIT NO 1
PHASE III RFI/RI WORK PLAN

FIGURE 2-13

SELENIUM CONCENTRATIONS IN UNCONFINED GROUND-WATER FLOW SYSTEM
Second Quarter 1989

October 1990



EXPLANATION

Individual Hazardous Substance Site (IHSS)

B301889 ○ Alluvial Monitoring Well

B304789 ● Bedrock Monitoring Well

0271 △ Pre-1986 Well

Strontium Concentration

1 5 Data in mg/l

u Analyzed but not Detected

Scale 1 = 300

0' 150' 300'

CONTOUR INTERVAL = 20'

U S DEPARTMENT OF ENERGY
Rocky Flats Plant
Golden, Colorado

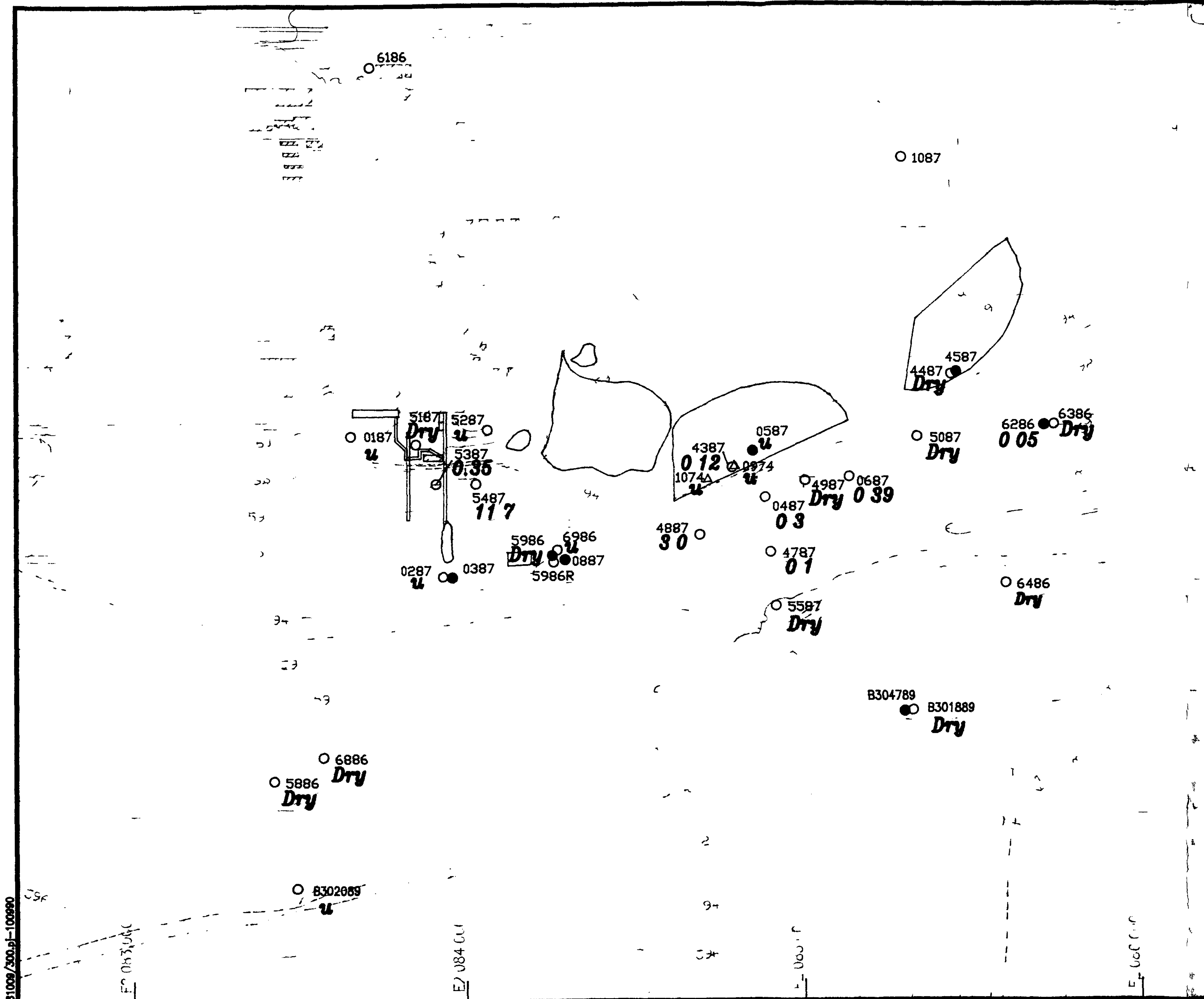
OPERABLE UNIT NO 1
PHASE III RFI/RI WORK PLAN

FIGURE 2-14

STRONTIUM CONCENTRATIONS IN UNCONFINED GROUND-WATER FLOW SYSTEM
Second Quarter 1989

October 1990

881011/300.pl-100990



EXPLANATION

Individual Hazardous Substance Site (IHSS)

B301889 ○ Alluvial Monitoring Well

B304789 ● Bedrock Monitoring Well

0271 △ Pre-1986 Well

Nickel Concentrations

0 6 Data in mg/l

u Analyzed but not Detected

Scale 1 = 300

0' 150' 300

CONTOUR INTERVAL = 20'

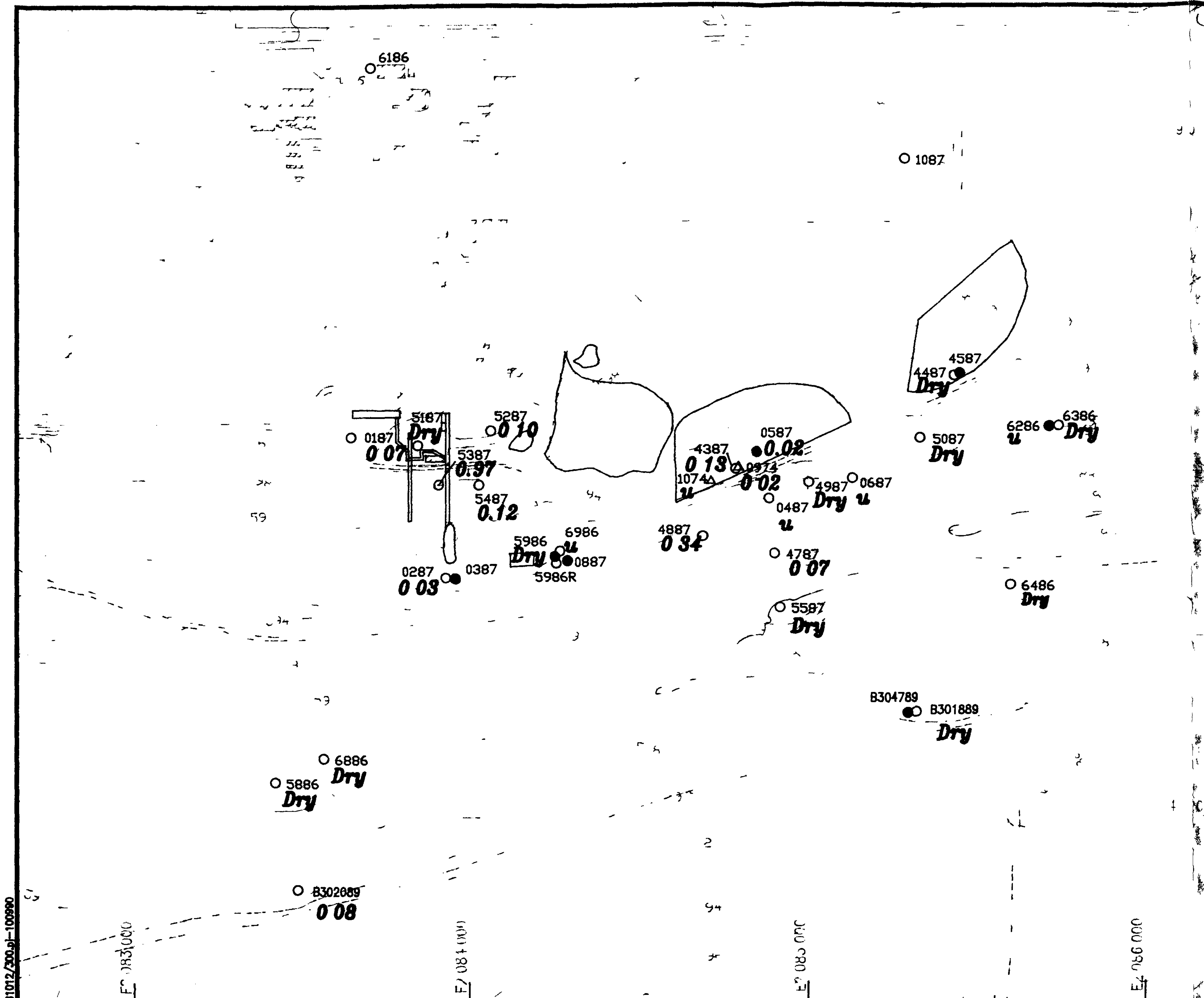
U S DEPARTMENT OF ENERGY
Rocky Flats Plant
Golden Colorado

OPERABLE UNIT NO 1
PHASE III RFI/RI WORK PLAN

FIGURE 2-15

NICKEL CONCENTRATIONS IN THE
UNCONFINED GROUND-WATER
FLOW SYSTEM
Second Quarter 1989

October 1990



EXPLANATION

Individual Hazardous Substance Site (IHSS)

B301889 ○ Alluvial Monitoring Well

B304789 ● Bedrock Monitoring Well

0271 △ Pre-1986 Well

Zinc concentrations

0 02 Data in mg/l

u Analyzed but not Detected

N

Scale 1 = 300

0' 150' 300'

CONTOUR INTERVAL = 20'

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Golden, Colorado

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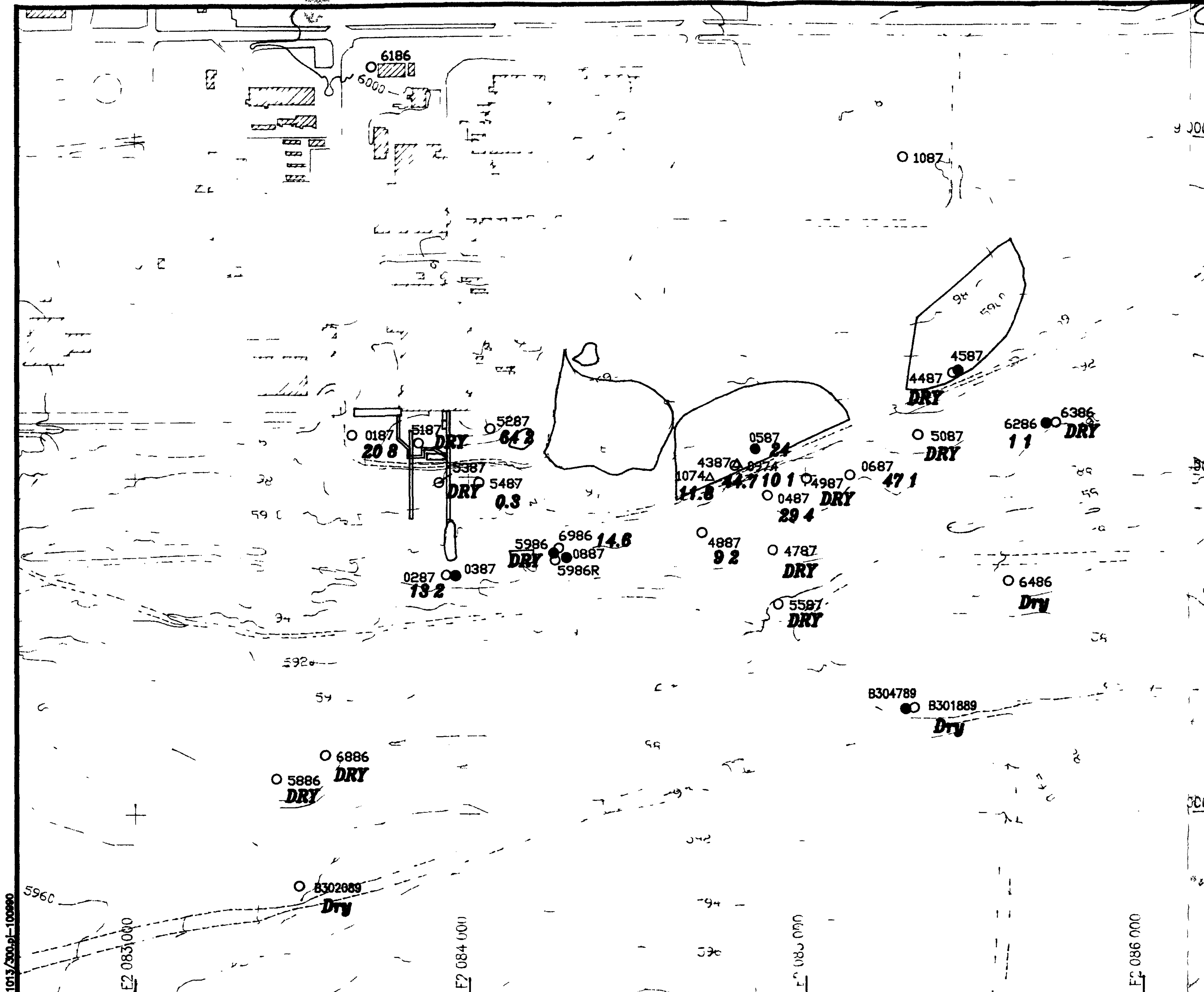
PHASE III RFI/RI WORK PLAN

FIGURE 2-16

ZINC CONCENTRATIONS IN THE UNCONFINED GROUND-WATER FLOW SYSTEM
Second Quarter 1989

October 1990



EXPLANATION

Individual Hazardous Substance Site (IHSS)

B301889 ○ Alluvial Monitoring Well

B304789 ● Bedrock Monitoring Well

0271 △ Pre-1986 Well

Uranium Concentrations

1 1 Data in pCi/l

ND No Data

Scale 1 = 300

0' 150' 300'

CONTOUR INTERVAL = 20'

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FIGURE 2-17

TOTAL DISSOLVED URANIUM IN THE UNCONFINED GROUND-WATER FLOW SYSTEM
Second Quarter 1989

October 1990

EXPLANATION

Individual Hazardous Substance Site (IHSS)

SW-35 Surface Water Monitoring Station

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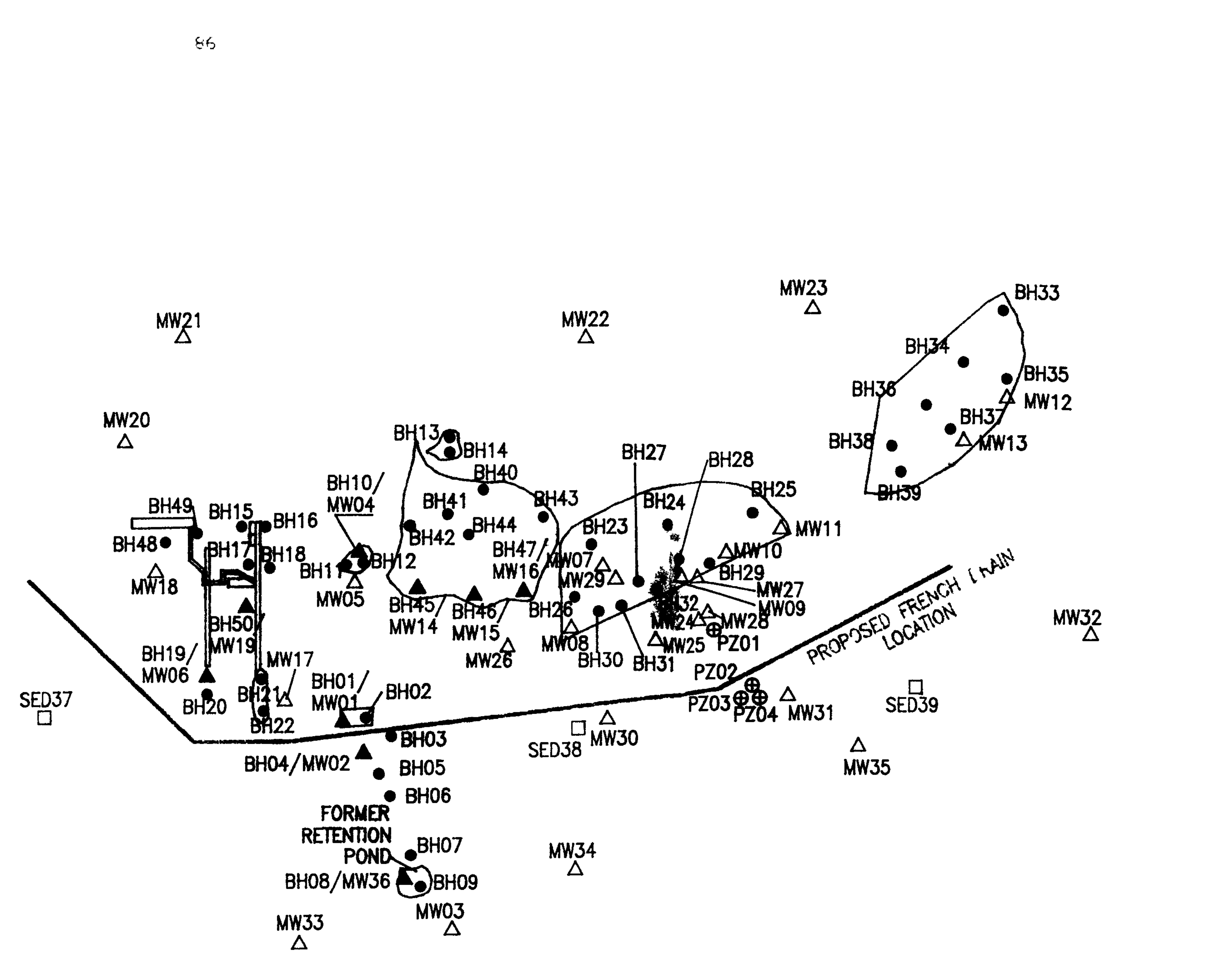
FIGURE 2-18

SURFACE WATER MONITORING STATION LOCATIONS

October 1990



EXPLANATION

Individual Hazardous Substance Site (IHSS)

Proposed French Drain Location

MW01 Proposed Monitor Well

BH01 Proposed Borehole

BH01/MW01 Proposed Borehole and Monitor Well

PZ01 Proposed Piezometer

SED39 Proposed Sediment Stations

Scale 1 = 300

0' 150' 300'

CONTOUR INTERVAL = 20'

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PHASE III RFI/RI WORK PLAN

FIGURE 5-1

PROPOSED PHASE III RFI/RI MONITOR WELL, BOREHOLE, PIEZOMETER, AND SEDIMENT STATION LOCATIONS

October 1990

901024/300-01-101090

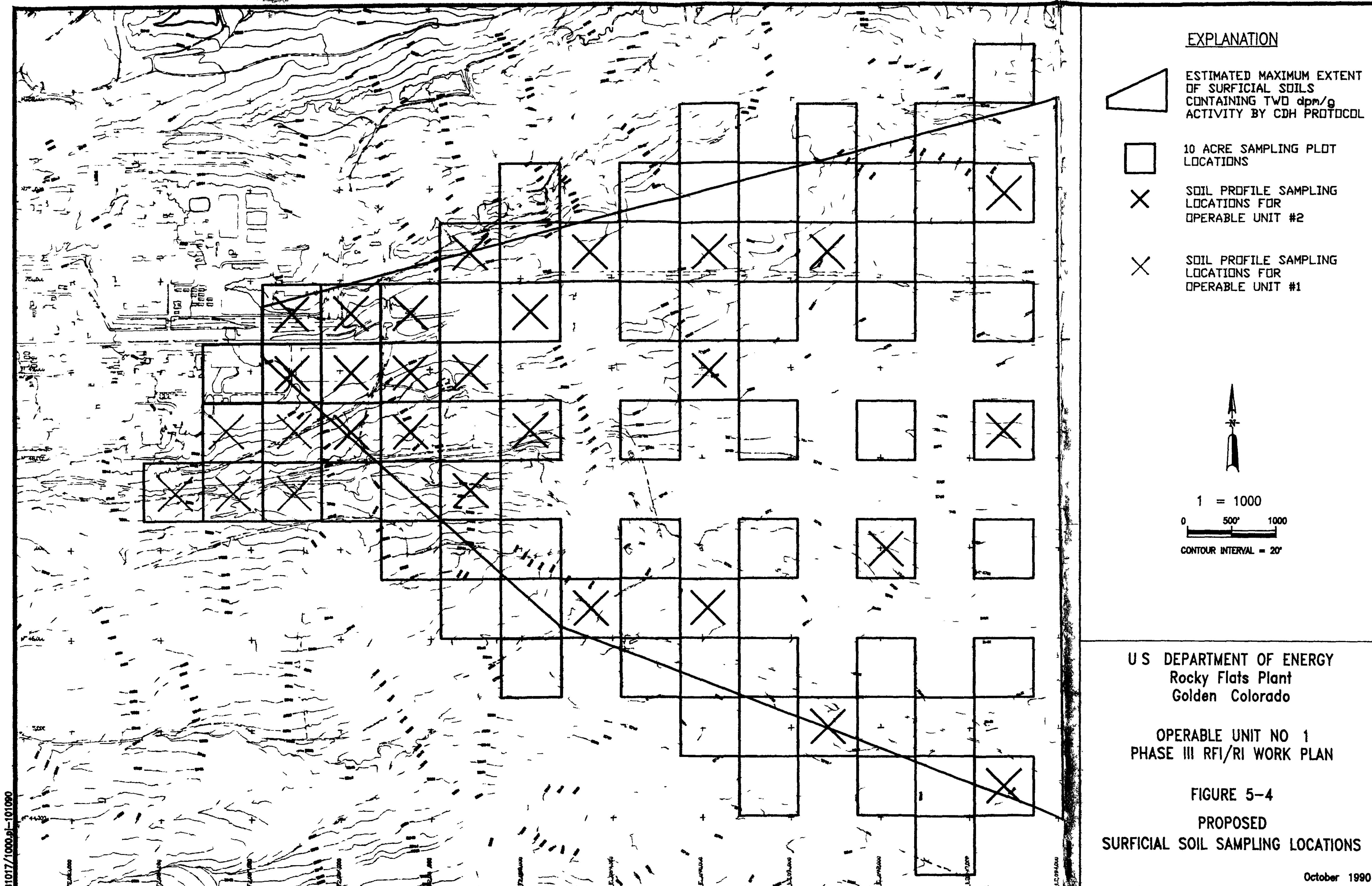

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FIGURE 5-4
PROPOSED
SURFICIAL SOIL SAMPLING LOCATIONS

October 1990

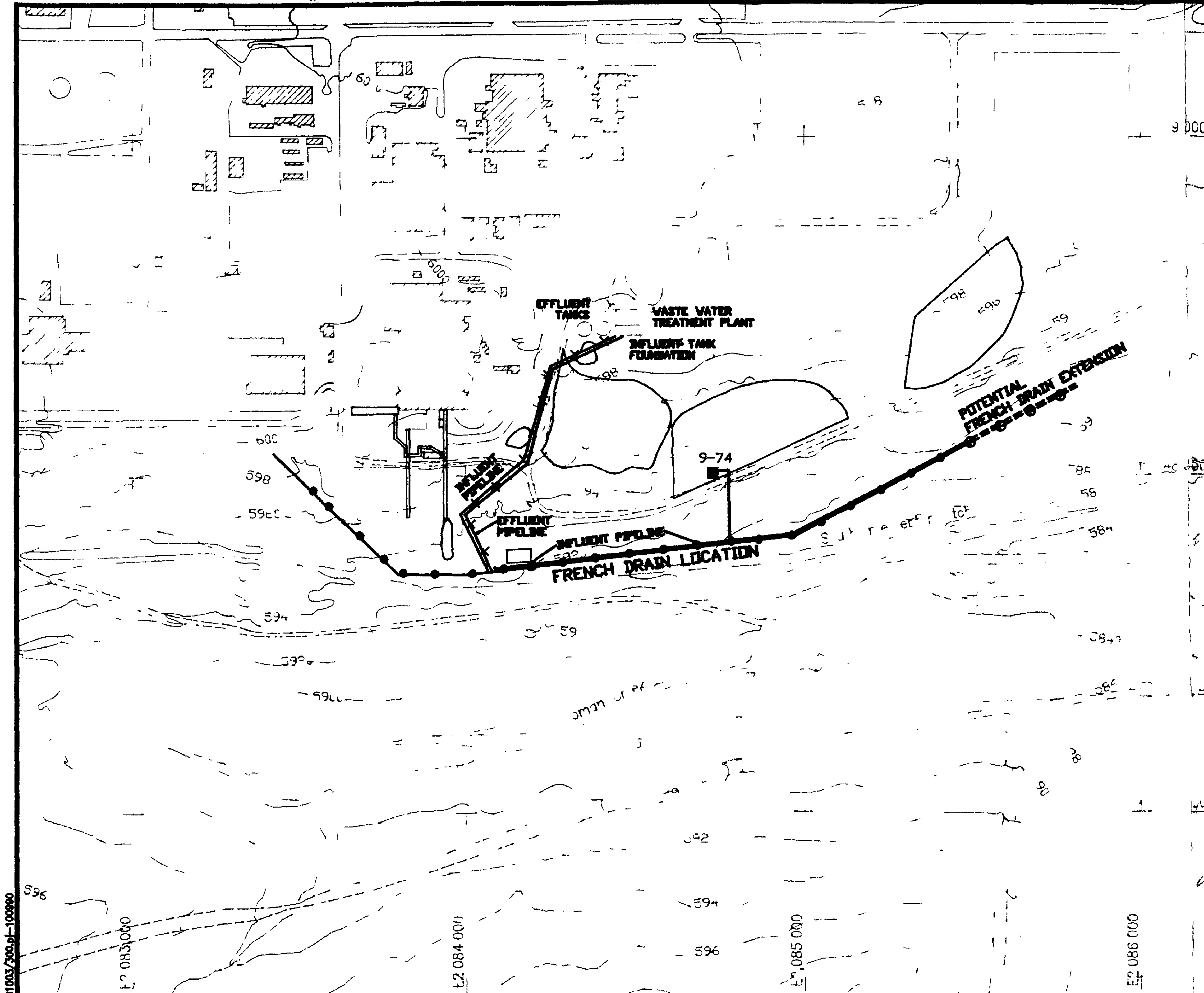

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FIGURE 5-5

INTERIM REMEDIAL ACTION
BOREHOLE LOCATIONS

October 1990

881003/300.pl-100990